UNIVERSIDADE DE LISBOA

Faculdade de Medicina Veterinária

BRACHYCEPHALIC OBSTRUCTIVE AIRWAY SYNDROME: A REVIEW WITH SIX CLINICAL CASES

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DISSERTAÇÃO DE MESTRADO INTEGRADO EM MEDICINA VETERINÁRIA

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LISBOA

Para a minha família

“Man selects only for his own good: Nature only for that of the being which she tends.”

— Charles Darwin, The Origin of Species

ACKNOWLEDGMENT

“Nothing is better than reading and gaining more and more knowledge.”

— Stephen Hawking

This quote reflects exactly what I did during my traineeship, I tried to absorb all the knowledge that people around me were willing to share. And then, with a blink of an eye, those 6 months were over.

I would like to thank my co-supervisor, Esmeralda Delgado, for accepting me, and for being so kind, patient and supportive.

To my supervisor, Susana Silva, for accepting me despite my lack of experience, for showing me the top quality care in veterinary medicine. And thank you for believing in me, for all the guidance, teaching and support during some difficult times.

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To my family for all the love and incredible support, I would not be able to go through this amazing adventure without you, since Azores to England and everything in between. To my mother for always being there, even at the difficult times. To my father for all the amazing support.

To each and everyone that was part of this journey, a big thank you, all your support lead me here.

ABSTRACT

"Brachycephalic Obstructive Airway Syndrome: A review with six clinical cases"

Brachycephalic breeds are well known to have respiratory issues due to anatomical changes in their skull such as stenotic nares, elongated soft palate and abnormal nasopharyngeal turbinates. These changes increase respiratory resistance, leading to a higher negative pressure – inspiratory pressure. With time this increased negative pressure will lead to the development of secondary changes, such as laryngeal collapse, palate and laryngeal oedema, swelling, saccule and tonsil eversion. All of this combined obstructs even further the upper respiratory tract. Animals usually presents exercise intolerance, stertous breathing, hyperthermia, snoring, and in some severe cases cyanosis and collapse may occur.

This prospective study aims to characterize a small sample of six brachycephalic dogs, relating their breed, age, gender, clinical presentation, primary changes and secondary changes detected. According to their clinical presentation the patients underwent individual surgical correction.

The pool sample consisted of 50% Pugs, 33% English bulldogs and 17% French bulldogs, with ages ranging from 5 months to 5 years old. The most frequent clinical signs were stertous breathing, 100%, exercise intolerance, 100%, regurgitation, 66.67%, retching, 66.67% and coughing, 50%.

After the brachycephalic obstructive airway syndrome (BOAS) investigation procedures, which included direct observation of the soft palate and larynx, radiographs, CT scan and bronchoscopy with BALs, the most common primary changes found were stenotic nares, 100%, and elongated/thick soft palate, 83.34%.

The secondary changes are chronic changes due the prolonged increased negative pressure. These were found in older patients, being the most frequent laryngeal saccules eversion, 40% and laryngeal collapse, 40%.

According to their clinical presentation and abnormalities found the patients underwent individual surgical correction. There are surgical techniques available to correct some components and secondary changes of this brachycephalic syndrome. The two major procedures are rhinoplasty, performed in all patients of this study and palatoplasty performed in 60% of patients.

Due the severe effects on quality of live one patient of this study was euthanized. All five cases that underwent surgical treatment had a good recovery, with no complications after the procedures. One week after the procedure the owners were contacted and reported improvements in the dog exercise time and breathing.

Keywords: Brachycephalic syndrome, BOAS, rhinoplasty, palatoplasty, tracheostomy, sleep apnoea.

RESUMO

“Síndrome respiratória obstrutiva dos braquicefálicos: Uma revisão com seis casos clínicos”

Raças de cães braquicefálicos são conhecidas por desenvolver problemas respiratórios relacionados com alterações anatómicas do seu crânio com estenose das narinas, prolongamento do palato mole e turbinados anormais nasofaríngeos. Estas alterações aumentam a resistência respiratória, culminando numa pressão negativa elevada – pressão inspiratória. Com tempo este aumento da pressão negativa leva ao desenvolvimento de alterações secundárias, como colapso da laringe, edema do palato e laringe, turgescência, eversão dos sáculos laríngeos e tonsilas. Todas estas alterações obstroem ainda mais as vias respiratórias superiores. Os animais normalmente apresentam intolerância ao exercício, respiração ruidosa, hipertermia, roncos, e em casos mais graves cianose e colapso podem ocorrer.

Este estudo prospetivo pretende de uma caracterizar uma pequena amostra de seis cães braquicefálicos, relativamente à raça, idade, género, sintomas/sinais clínicos, exame imagiológicos, decisão terapêutica e prognóstico, e a sua comparação com a bibliografia, alterações primárias e secundárias.

A amostra consiste em 50% Pugs, 33% Bulldog inglês e 17% Bulldog francês, com idades variando entre 5 meses a 5 anos. Os sinais clínicos mais frequentes foram respiração ruidosa, 100%, intolerância ao exercício, 100%, regurgitação, 66.67, esforço para vomitar, 66.67% e tosse, 50%.

Após aos procedimentos de investigação da síndrome, que incluíam observação direta do palato mole e laringe, radiografias, tomografia axial computadorizada (TAC) e broncoscopia com lavagem broncoalveolar (LBA), as alterações primárias mais frequentemente encontradas foram estenose das narinas, 100%, e prolongamento/espessura do palato mole, 83.34%.

As alterações secundárias tem caracter crónico devido ao aumento prolongado da pressão negativa. Estas são encontradas em pacientes mais velhos, sendo as mais frequentes eversão dos sáculos laríngeos, 40% e colapso da laringe, 40%.

De acordo com a sua apresentação clinica e alterações encontradas os pacientes foram submetidos a correção cirúrgica personalizada. Existem técnicas cirúrgicas para corrigir alguns componentes e alterações secundárias desta síndrome dos braquicefálicos. Os dois procedimentos principais são rinoplastia, realizada em todos os pacientes deste estudo, e palatoplastia realizada em 60% dos pacientes.

Palavras-chave: Síndrome respiratória obstrutiva do braquicefálico; rinoplastia; palatoplastia; traqueostomia, apneia do sono.

TABLE OF CONTENTS

INDEX OF FIGURES

INDEX OF TABLES

Abbreviations

ACP – Acepromazine

BAL - Bronchoalveolar Lavage

BAS – Brachycephalic Airway Syndrome

BOAS – Brachycephalic Obstructive Airway Syndrome

BSAVA – British Small Animal Veterinary Association

CRI – Constant Rate Infusion

CT – Computed Tomography

Fig. – Figure

GA – General Anaesthetic

GI – Gastrointestinal

GIT – Gastrointestinal tract

IM – Intramuscular

IV - Intravenous

LBA – Lavagem bronco-alveolar

MRI - Magnetic Resonance Imaging

NSAIDs – Non Steroidal Anti Inflammatory Drugs

$PaCO_2$ - Arterial Partial Pressure of Carbon Dioxide

PaO_2 - Arterial Partial Pressures in Oxygen

PCV – Packed Cell Volume

PO – Per Os

qh4 – Every four hours

qh5 – Every five hours

REM – Rapid Eye Movement

SC – Subcutaneous

SpO_2 - Peripheral capillary oxygen saturation

TAC – Tomografia axial computadorizada

TS – Total Solids

UAL – Unilateral Arytenoid Lateralisation

UK – United Kingdom

URT – Upper Respiratory Tract

VD – Ventro-dorsal

CHAPTER I - PLACEMENT

The student attended the Vets Now Referrals in Swindon, from September 28th 2015 to January 5th 2016 and Highcroft Veterinary Referrals, in Bristol, from January 7th 2016 to 24th March 2016.

The Vets Now group works exclusively with referral cases from internal medicine, surgery, dermatology, emergency and critical care and exotics. It offers 24 hours emergency care, ambulance service, hospitalization, isolation, soft tissue and orthopaedics surgery, ultrasound, endoscopy, radiology, computed tomography (CT) on site and magnetic resonance imaging (MRI).

The day would start at 08h30 with morning rounds, presentation and discussion of the hospitalized patients, followed by their clinical examination. Throughout the day, the student would assist and observe consults and diagnostic procedures, surgeries, blood analysis and monitoring of patients.

The student curricular placement had emphasis in following investigation of clinical cases, including attending consultations, placement of catheters, collection of blood samples, and their analysis in house and interpretation, monitoring and treatment of hospitalised patients and also assisting in other procedures such as ultrasound, radiographs, CT scan and MRI, anaesthesia.

The Highcroft Veterinary Referrals group offers first opinion and referral service on the same building, this makes the referral of more complicated cases easier. It offers referral services of internal medicine, surgery, including laparoscopic surgery, cardiology, dermatology, ophthalmology, diagnostic imaging, emergency and critical care, rehabilitation and exotics. Highcroft Referrals offers hospitalization, ambulance service, 24 hours emergency care, isolation, ultrasound, and endoscopy, CT on site, radiology, fluoroscopy and interventional surgery.

This placement included activities regarding assisting in consults, hospitalization and diagnostic investigation and/or surgery. Cardiology, dentristry, emergency and critical care medicine, gastroenterology, haematology, infectious diseases, ophthalmology, orthopaedics, diagnostic imaging and transfusion medicine. The student assisted in anaesthetic monitoring, echocardiography, electrocardiogram, bronchoscopy, gastroscopy, laparoscopic spays, laboratorial screening, CT scans, radiography and ultrasonography.

CHAPTER II - BRACHYCEPHALIC OBSTRUCTIVE AIRWAY SYNDROME: A REVIEW WITH SIX CLINICAL CASES

1.0 INTRODUCTION

The domestic dog might be the most morphologically diverse mammalian species known to man. It has been artificially bred throughout the years to meet desired functional and aesthetic standards, which lead to the human creation of over 400 dog breeds (O'Neill, Jackson, Guy, Church, McGreevy, Thomson & Brodbelt, 2015). The skull shape is one of the majors defining features of breeds, and it can be categorised as dolichocephalic (long and slender skull), mesaticephalic (intermediate skull conformation) or brachycephalic (short and wide skull) (O'Neill *et al*, 2015).Brachycephaly is a discrete mutation that has been artificially selected for in many popular dog breeds (Packer, Hendricks, Tivers & Burn, 2015). Brachycephalic breeds, such as English and French bulldogs, Pugs and Boxers, are increasingly common, becoming especially popular in the last years (O'Neill *et al*, 2015; Oechtering, 2010). It is know that many brachycephalic breeds have respiratory disorders related with the skull conformation (O'Neill *et al*, 2015).

The respiratory tract, as we know it, is divided in two major parts, the upper and the lower airways (Hoffman, 2007). The upper airway consists of the nasal cavities, nasopharynx and oropharynx, and larynx (Hoffman, 2007; Clarke, 2015). This component is responsible for treating the air, assuring a right temperature and humidity, and for preventing any particles to damage the lower airways (Hoffman, 2007). The lower airways are composed by trachea, bronchi and bronchioles (Hoffman, 2007). This component is responsible for conducting the air to the lungs (Hoffman, 2007). The narrowest passage of the airflow is the rima glottis, which is delimited dorsally by the paired arytenoid cartilages and ventrally by the paired vocal folds (Koch, Arnold, Hubler & Montavon, 2003).

It is know that diseases of the lower respiratory airways attracts most of the attention of veterinarians, but abnormalities in the upper airway can bring major consequences to the air flow, such as brachycephalic airway syndrome (Hoffman, 2007).

Brachycephalic obstructive airway syndrome (BOAS) is the clinical presentation of upper air obstruction due to a combination of the anatomical abnormalities in the upper respiratory tract (URT) of brachycephalic dogs and cats (Moores & Anderson, 2010).

Common brachycephalic dog breeds include English Bulldogs, French Bulldogs, Boston bull terrier, Pugs, Pekingese, Boxers and in the UK, the Cavalier King Charles (Meola, 2013). In cats the brachycephalic breeds are Persian and Himalayan (Meola, 2013). Most brachycephalic breeds develop brachycephalic airway syndrome (BAS) due to the anatomical changes in their skull – the normal length lower jaw with a non-proportional shorter upper jaw (Lodato & Hedlund, 2012). Due to the shape of their skull, these breeds not only suffer from respiratory problems but are also predisposed to other conditions such as hydrocephalus, facial nerve paralysis, skinfold dermatitis, eye-bulb prolapse, and abnormal positioning of the teeth (Kosh, Arnold, Hubler & Montavon, 2003). A hyperplastic tongue is also frequently encountered in brachycephalic breeds that, in addition to nasopharyngeal mucosal hyperplasia, contributes to narrowing of the nasopharyngeal space (Poncet, Dupre, Freiche & Bouvy, 2006; Findji & Dupre, 2013; Dupre, 2008).

A recent study by O'Neill *et al* (2015) with 200 dogs from three extreme brachycephalic breeds (English bulldog, French bulldog and Pug), one moderate brachycephalic breed (Yorkshire terrier) and two non-brachycephalic breed (Border terrier and West highland terrier) concluded that the proportion of dogs with at least one URT disorder in the extreme brachycephalic group was higher than in the moderate and non-brachycephalic group (22.0% vs 9.7%) and also varied between the breeds: English bulldogs 19.5%, French bulldogs 20.0%, Pugs 26.5%, Yorkshire terrier 13.0%, Border terrier 9.0% and West highland terrier 7.0%. Yet from the same study, extreme brachycephalic breeds were 3.5 times more likely to have at least one URT disorder compared with the moderate and non-brachycephalic group.

Packer, Hendricks, Tivers & Burn (2015) reported that the top three highest risk breeds for BOAS are the Pug, French bulldog and Bulldog. O'Neill *et al* (2015) did not found evidence of sex predisposition for brachycephalic obstructive airway syndrome (BOAS).

The primary changes of BOAS are anatomical changes, such as stenotic nares, elongated soft palate, and in some cases aberrant nasopharyngeal turbinates and hypoplastic trachea (Meola, 2013; O'Neill *et al*, 2015; Lodato & Hedlund, 2012; Clarke, 2015). Some authors, like Koch *et al* (2003) include in BOAS enlarged tonsils and narrowed rima glottis. Individual dogs may have one, or a combination of URT conditions which can predispose to others URT disorders that combined describe an overall brachycephalic airway syndrome (BAS) (O'Neill *et al*, 2015).

These anatomical primary changes increase air turbulence and airway resistance which can cause the development of secondary changes (palate and laryngeal oedema, swelling, saccule and tonsil eversion and laryngeal collapse) which can lead to life threatening respiratory compromise (Meola, 2013). Due to this an early diagnosis and surgical intervention is beneficial and imperative for the life quality of the patient as it can decrease the likelihood of development of secondary changes (Lodato & Hedlund, 2012).

1.1 ANATOMICAL ABNORMALITIES

As mentioned before, BOAS is a debilitating respiratory syndrome that affects brachycephalic dogs, where the airways are obstructed by soft tissue during respiration (Packer, Hendricks, Tivers & Burn, 2015).

It is know that many brachycephalic breeds have respiratory disorders related to the skull conformation (O'Neill *et al*, 2015). These skull anatomical changes are secondary to an early ankyloses of the basicranial epiphyseal cartilage of the skull, which leads to chondrodysplasia of the longitudinal axis of the skull (Meola, 2013). This means that brachycephalic breeds skull has a normal width but is significantly reduced in length (Brown & Gregory, 2005) and that it has a normal length of the lower jaw but a shorter upper jaw (Lodato & Hedlund, 2012). As the amount of soft tissue is not proportionally reduced to the shorter maxilla, the redundant soft tissue leads to obstruction of the airway length (Brown & Gregory, 2005).

As the dog matures, the compacted soft tissue progressively blocks the airflow, obstructing the larynx and nasopharynx, and impairs the thermoregulatory function of the nose through nasal obstruction (Packer, Hendricks, Tivers & Burn, 2015). In the great majority of dogs, this disorder is usually diagnosed at 2 or 3 years of age, however it can occur early, especially in English bulldogs and Pugs (Meola, 2013; Lodato & Hedlund, 2012; Moores & Anderson, 2010). Brachycephalic dogs may also have a dyschondroplastic development of the limbs, resulting in relatively short and bowed legs (Moores & Anderson, 2010).

Within the nose of the young brachycephalic dog, the turbinates continue to growth despite the midface has stopped to grow, resulting in an oversized turbinates (Packer, Hendricks, Tivers & Burn, 2015) which obstruct even further the airflow. This abnormal nasopharyngeal turbinates have not been classified as primary or secondary change of BOAS (Lodato & Hedlund, 2012).

The stenotic nares are a primary anatomical change and result from medial collapse of the lateral wings of the nostrils, which leads to smaller and narrow nares (Brown & Gregory, 2005). This increases the airway resistance, requiring a higher negative pressure to overcome the inspiratory flow limitation (Hoffman, 2007). This increased negative pressure results in further collapse of the wing of the nostril, and this narrowing leads to an even greater inspiratory effort by the diaphragm, intercostal muscles and chest wall muscles (Hendricks, 2004).

The chronically increased negative pressure leads to constant stretching and inflammation of the URT tissues, which predisposes to the already mentioned secondary changes (O'Neill *et al*, 2015). This negative pressure is especially noted in the pharynx (Hendricks, 2004); the consequences on the lower airways and pulmonary parenchyma are largely unknown (Mellema & Hoareau, 2015).

1.2 RESPIRATION CHANGES

Brachycephalic dogs have shown to have a significantly lower expiratory time-to-inspiratory time ratios, lower peak inspiratory flows, and higher peak expiratory flows when compared with non-brachycephalic dogs (Mellema & Hoareau, 2015; Bernaerts, Talavera, Leemans, Hamaide, Claeys, Kirschvink & Clercx, 2010). The decrease in expiratory time-to-inspiratory time, indicates a longer inspiratory time relative to expiratory time (inspiratory dyspnoea), which is consistent with the expected flow limitation during inspiration when anomalies are encountered in the extrathoracic part of the system (Bernaerts *et al*, 2010). The decrease in peak inspiratory flows has been reported in dogs with a fixed upper airway obstruction (Bernaerts *et al*, 2010).

The collapsed URT requires a longer period of contraction from inspiratory muscles prolonging the inspiratory phase (Reiter & Holt, 2012) and the increased intra-pleural pressure upon expiration collapses the intrathoracic trachea and mainsteam bronchi, which results in prolonged expiration (Clarke, 2015). Reiter & Holt (2012) also believe that the expiratory muscles force end-respiratory volume below passive functional residual capacity, storing elastic energy in the chest wall for inspiration, which allows substantial airflow before the onset of inspiratory muscle contraction.

According to Monnet (2006) these respiratory changes are indicative of an obstructive breathing pattern. In brachycephalic breeds this obstructive breathing pattern is encountered even if the airway diameter is compromised by less than 50% (Monnet, 2006) whereas in non-brachycephalic breeds a reduction of over 50% of the airway diameter is required to modify the breathing pattern (Monnet, 2006).

1.3 THERMOREGULATION

It is well known fact that brachycephalic dogs also suffer from severe heat susceptibility (Noller, Hueber, Aupperle, Seeger, Oechtering, Niestrock, & Oechtering, 2008). Panting is a major method of thermoregulation in dogs as it increases minute ventilation and enhances heat dissipation (Clarke, 2015). Panting is an evaporation mechanism, in which the richly vascularized surface from the nasal turbinates loses heat to the airflow allowing cooling of the animal (Noller *et al*, 2008). In order for this mechanism to function properly a non-obstructed intranasal flow during inspiration and an undisturbed oral expiration are essential (Noller *et al*, 2008).

Noller *et al* (2008) research concluded that brachycephalics have an obstructed nasal and nasopharyngeal influx alongside impairment of the expiratory airflow (expiration). All of these facts support the assumption that heat and stress lead to primary failure of the peripheral thermoregulation (Noller *et al,* 2008).

Heat, humidity, excessive activity or excitement must be avoided in brachycephalic breeds, as panting increases airflow turbulence leading to inflammation and swelling of the airways causing further blockage of already narrowed airways (Lodato & Hedlund, 2012). In this setting, hyperthermia and heat stroke are common findings in brachycephalic dogs (Clarke, 2015).

2.0 COMPONENTS OF BOAS

Several studies (Poncet, Dupre, Freiche & Bouvy, 2006; Dupre, 2008; Riecks, Birchard & Stephens, 2007) report the most common abnormalities to be elongated soft palate, stenotic nares, laryngeal saccule eversion and laryngeal collapse.

It is important to take in count that these components can differentially influence BOAS severity and clinical signs, which depend on the breed and animal behaviour (Haimel & Dupré, 2015). French bulldogs suffering from BOAS show a high prevalence of gastroesophageal signs (Poncet, Dupre, Freiche & Bouvy, 2006), whereas Pugs are more likely to be affected by nasopharyngeal turbinates and laryngeal and bronquial collapse (Ginn, Kumar, McKiernan, Powers, 2008; De Lorenzi, Bertoncello & Drigo, 2009).

2.1 PRIMARY CHANGE: STENOTIC NARES

The external nose is composed by hairless epidermis and underlying mobile cartilaginous structures; the openings of the nose are known as nares or nostrils (Ellison, 2004).

The cartilaginous nose consists of an unpaired cartilaginous septum and the paired dorsolateral, paired ventrolateral, and paired accessory cartilages (Ellison, 2004). These cartilages are connected to the dorsal portion of the osseous muzzle by three ligaments: single dorsal nasal ligament and a paired lateral nasal ligaments (Ellison, 2004). Wykes (1991) believes that in young and small breed dogs, these ligaments are poorly developed and may explain why the nares often collapse in brachycephalic breeds (*in* Ellison, 2004).

The stenotic nares are a primary anatomical change and results from a medial collapse of the lateral wings of the nostrils (adduction of the alae), which leads to a smaller and narrow opening at the external nares (Brown & Gregory, 2005) (Figure 01).

Figure 01. Severely stenotic nares in an 1 year old French Bulldog. (Original picture)

BOAS is a good illustration of Poiseuille law (Q = $\pi\Delta Pr4/8\eta l$, Q is the rate flow; ΔP is the pressure difference the ends of the airway; r is the radius of the airway; η is the viscosity of the gas; and l is the length of the airway), in which the air flow resistance is inversely proportional to the fourth power of the tube radius, meaning that a small reduction in the airway diameter leads to a great increase in the airflow resistance (Reiter & Holt, 2012). In non-brachycephalic breeds, airflow through the nasal cavities is responsible for 76.5% of total airflow resistance, in brachycephalic breeds the nasal cavity resistance can cause increases up to 80% (Lodato & Hedlund, 2012). This smaller and narrow opening increases the airway resistance, which requires a higher negative pressure to overcome the inspiratory flow limitation (Hoffman, 2007).

This could all be avoided if the dogs breathe through their mouths, but unfortunately dogs are exclusively nose breathers (Koch *et* al, 2003). Even if nasal resistance is artificially increased, dogs still try to breathe through their noses instead of the mouth (Koch *et al*, 2003).

The increased inspiratory negative pressure results in further collapse of the wing of the nostril, and an even higher negative pressure that will lead to the secondary changes (Brown & Gregory, 2005). Whenever the negative pressure is excessively greater than the atmospheric pressure, the tissues become inflamed, tonsils and laryngeal saccules evert, and the cartilaginous larynx and trachea become compromised and can collapse; all these changes decrease the lumen even further, which will increase the resistance to airflow and aggravate the respiratory compromise (Lodato & Hedlund, 2012). All these secondary changes lead to further deterioration that may ultimately cause death by suffocation (Koch *et al*, 2003).

Oechtering (2010) reports a new anatomical constriction in brachycephalic dogs – stenosis of the nasal vestibule caused by the inner part of the nasal wing. The author explains that unlike humans, the nasal vestibule in dogs is not empty, it is filled to a large extent by the voluminous, caudally extending nasal wing, which then merges into the alar fold. The ala is too large for the nose, and presses against the septum from the lateral aspect (Fig. 02) (Oechtering, 2010). This explains why some dogs only show slight improvements after rhinoplasty and therefore surgeon need to be aware of this feature to make sure that the surgical incision in deep enough to improve the airflow (Oechtering, 2010).

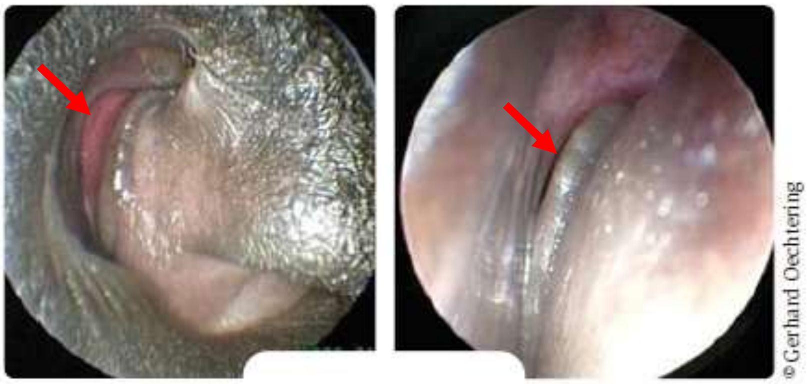


Fig. 02. Nasal opening - internal view of the nasal vestibule with nasal septum and nasal wing (arrow). Left: normal dog. Right: brachycephalic. (Adapted from Oechtering, 2010).

2.2 PRIMARY CHANGE: ABERRANT NASOPHARYNGEAL TURBINATES

The unique anatomy of the brachycephalic skull provides the explanation for the development of the nasopharyngeal turbinates (Ginn, Kumar, McKiernan & Powers, 2008). The nasal turbinates and other bones of the skull are derived from the neural crest ectoderm, and these bones can have a membranous ossification or an endochondral ossification (Ginn *et al*, 2008). The nasal capsule (maxilla, incisive, palatine and nasal bones) is formed by membranous ossification, which mean that it can mold around the structures it encloses and tends to ossify earlier during development (day 28 of the gestational period) (Ginn *et al*, 2008). The nasal turbinates are formed by endochondral ossification and therefore they continue to grow and ossify beyond the gestational period; these bones are less plastic and tend to grow to their full extent (Ginn *et al*, 2008).

In brachycephalic breeds the ethmoid turbinate complex may tend to protrude into the nasopharynx due to the limited space in the already ossified nasal capsule (Fig. 03) (Ginn *et al*, 2008). These are abnormal turbinates that extend caudally from the choanae into the nasopharynx and may play a role in the upper airway obstruction (Meola, 2013).

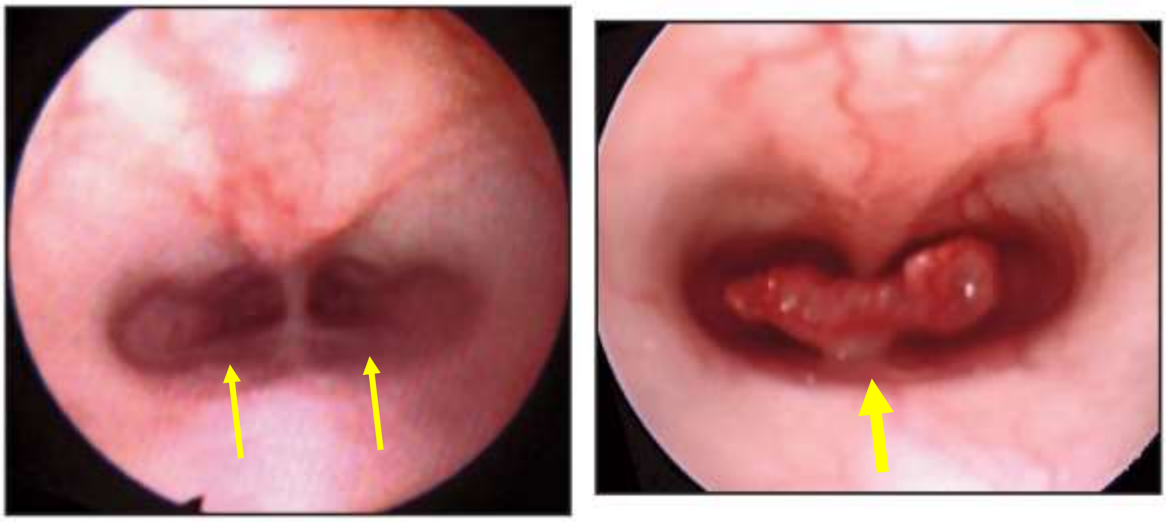


Fig. 03. The picture on the left shows a normal nasopharynx in a brachycephalic dog (arrows). The picture on the right shows the nasopharynx of brachycephalic dogs with nasopharyngeal turbinates (arrow). In both pictures were obtained from a retroflexion of an endoscope dorsally and cranially behind the soft palate – vomer bone is dorsally and the soft palate is ventrally Adapted from (Ginn, Kumar, McKiernan & Powers, 2008).

Oechtering, Oechtering & Noeller (2007) compared the nose structure between brachycephalic dogs and normocephalic dogs via CT and concluded that, in some brachycephalic dogs, part of the airway occlusion is due aberrant turbinates – rostral turbinates that extend into the nasal cavity and caudal turbinates that extend into the nasopharynx.

Aberrant nasopharyngeal turbinates are present in around 21% of brachycephalic animals, including 21% of dogs and 20% of cats (Ginn *et al*, 2008). In this author study, 82% of dogs with aberrant nasopharyngeal turbinates were Pugs. In Bernaerts *et al* (2010) study, the incidence of nasopharyngeal turbinates abnormalities was similar and also described this abnormality for the first time in English Bulldogs.

The abnormalities in the nasopharyngeal turbinates are diagnosed with rhinoscopy or with observation of the nasopharynx with flexible endoscope; the lack of these diagnostic tools leads to potential underdiagnosing of this BOAS feature (Ginn *et al*, 2008).

The presence of specific clinical signs attributable to nasopharyngeal turbinates is uncertain, but is a reasonable assumption that they may contribute to upper airway obstruction (Ginn *et al*, 2008).

Ginn *et al* (2008) believes that to ascertain the true incidence of nasopharyngeal turbinates abnormalities in the brachycephalic population, a prospective study is needed where both clinically normal brachycephalic animals and BOAS affected animals would undergo rhinoscopy to screen for nasopharyngeal turbinates since abnormal nasopharyngeal turbinates has only been reported in brachycephalic breeds.

2.3 PRIMARY CHANGE: ELONGATED SOFT PALATE

In a normal dog the tip of the soft palate ends slightly rostrally to the tip of the epiglottis (Meola, 2013). Another major primary anatomical abnormality in brachycephalic breeds is the elongated soft palate (Meola, 2013). Lorinson *et al* (1997) reports that in dogs with clinical signs of BOAS, the soft palate is considered too long in the majority (> 85%) of cases (*in* Brown & Gregory, 2005). Lodato & Hedlund (2012) report that elongation of the soft palate is diagnosed in 80% to 100% of patients with BOAS. Riecks, Birchard & Stephens (2007) also report that the soft palate the most common abnormality in around 87.1% of brachycephalic dogs with BOAS. The elongation of the soft palate does not appear to be a feature in cats with BAS (Brown & Gregory, 2005).

Once again this is a consequence from the shorter length of the skull. The tip of the soft palate extends past the epiglottis, and it may be sucked into the glottis (Brown & Gregory, 2005). An elongated soft palate is one that extends more than 1 to 3 mm caudal to the tip of the epiglottis (Hedlund, 2007). This abnormality increases the air flow resistance, and is usually the cause of the characteristic snore and stertorous breathing (Meola, 2013). In these breeds the soft palate is not just elongated, but it can also be thickened (Hedlund, 2007).

2.4 HYPOPLASTIC TRACHEA

Some authors believe that the presence of hypoplastic trachea in brachycephalic breeds is due to an abnormal embryogenesis, and not a sequela of a more cranially situated stenosis (Koch *et al*, 2003).

In one study by Riecks, Birchard & Stephens (2007) none of the dogs had a diagnosis of hypoplastic trachea alone. In this author’s opinion, this does not imply that hypoplastic trachea is a secondary problem, and it should be considered another independent component of brachycephalic syndrome.

Currently there is no consensus in the role of hypoplastic trachea relation with the BAS. One thing the authors seem to agree is that English bulldogs seem to be predisposed to tracheal hypoplasia (Lecoindre & Richard, 2004). Riecks, Birchard & Stephens (2007) reported that there is no significant difference in the long-term outcome between dogs with a hypoplastic trachea and dogs with a normal tracheal diameter

2.5 TRACHEAL AND BRONCHIAL COLLAPSE

BAS is a well described syndrome, however abnormalities of the lower respiratory tract (trachea, principal bronchi and lobar bronchi) have never been systematically evaluated by bronchoscopy (De Lorenzi, Bertoncello & Drigo, 2009).

De Lorenzi, Bertoncello & Drigo (2009) believe that the chronic airway obstruction and chronic increased negative pressure, since birth, leads to detectable abnormalities, such as bronchial collapse and tracheal collapse. Brachycephalic breeds are much more predisposed to dynamic obstructions of the URT due their obstructed air passageways (De Lorenzi, Bertoncello & Drigo, 2009). During both respiratory phases, a pressure gradient develops across the walls of the airways; this gradient interfere with the diameter of the collapsible portions of the airways leading to changes in the airway resistance (De Lorenzi, Bertoncello & Drigo, 2009). Dynamic airway collapse usually occurs during inhalation in the extrathoracic portion of the airways, and it occurs during forced exhalation in the intrathoracic portion (De Lorenzi, Bertoncello & Drigo, 2009).

Due to the increased negative pressure, brachycephalic dogs use their accessory respiratory muscles during exhalation, as a consequence they make a greater effort to exhale increasing the pleural pressure, which increase the transmural pressure across the wall of the intrathoracic airways leading to their collapse (De Lorenzi, Bertoncello & Drigo, 2009).

In a study with 40 dogs, only one dog showed tracheal collapse while bronchial collapse was a much more common finding. The left side bronchi were significantly more often affected than the right side bronchi but the reasons are unknown (De Lorenzi, Bertoncello & Drigo, 2009). This study also found that Pugs have a higher risk of bronchial collapse than other brachycephalic breeds which could explain their predisposition for cranial left lung lobe torsion (De Lorenzi, Bertoncello & Drigo, 2009).

2.6 SECONDARY CHANGE: LARYNGEAL SACCULES EVERSION

Laryngeal saccules eversion is a common secondary change found in BAS (Meola, 2013). It is encountered in 40% to 60% of patients with BOAS (Lodato & Hedlund, 2012). Laryngeal saccules eversion is caused by the increase in negative pressure during inspiration and air turbulence (Brown & Gregory, 2005).

The pre-existing primary nasal obstruction (stenotic nares) or pharyngeal obstructions (elongated soft palate) requires a higher pressure gradient to draw air into the lungs, resulting in very low airway pressure through the larynx (Brown & Gregory, 2005). Due to the low pressure in the larynx, the tissue just rostral to the vocal cords is pulled into the ventral glottis, further obstructing the already narrowed airway lumen and creating air turbulence, that will lead to vibration and tissue oedema which will worsen the air flow (Brown & Gregory, 2005; Lodato & Hedlund, 2012). This is the reason why laryngeal saccules eversion is more commonly found in dogs with a prolonged history of upper airway obstruction (Brown & Gregory, 2005).

As will be discussed ahead, the saccule eversion is the first stage of laryngeal collapse (Lodato & Hedlund, 2012).

2.7 SECONDARY CHANGE: LARYNGEAL COLLAPSE

Laryngeal collapse is another frequent secondary change frequently seen in dogs that are older on first presentation, even if their clinical signs are milder, which reflects the time it takes for collapse to manifest (Meola, 2013; Moores & Anderson, 2010). The chronic increased inspiratory effort and abnormal air pressures leads to tiredness and loss of rigidity of the laryngeal cartilages and laryngeal collapse due to medial deviation of the corniculate and cuneiform processes (Brown & Gregory, 2005).

This progressive condition in characterized by loss of support of the laryngeal cartilages and although it is more commonly seen in middle-aged to older dogs with severe BAS it has been reported in young patients (Mercurio, 2011).

Recent papers suggest that Pugs have a high incidence of laryngeal and bronchial collapse (Hedlund, 2007; De Lorenzi *et al*, 2009) which was also reported by Haimel and Dupre study (2015). Haimel and Dupre (2015) report that Pugs have higher grades of laryngeal collapse when compared with French bulldogs with the same level of clinical signs. The authors also concluded that the improvement of respiratory signs following folded flap surgery did not differ between these two breeds despite the presence of the laryngeal collapse.

The British Small Animal Veterinary Association (*in* Brown & Gregory, 2005) divided the laryngeal collapse in 3 stages (Fig. 04):

> Stage I: Chronic subatmospheric airway pressure causes eversion of the laryngeal saccules, which results in further progressive glottic obstruction. Eventually, there can be distortion and collapse of both the cuneiform and corniculate process of the arytenoid cartilage of the larynx, termed “laryngeal collapse”.
>
> Stage II: The cuneiform processes of the arytenoid cartilage and the fold of tissue connecting them to the epiglottis (aryepiglottic folds) weaken and deviate medially causing obstruction of the ventral aspect of the glottis.

Stage III: The corniculate processes of the arytenoid cartilage lose their rigidity and deviate medially, obstructing the dorsal aspect of the glottis.

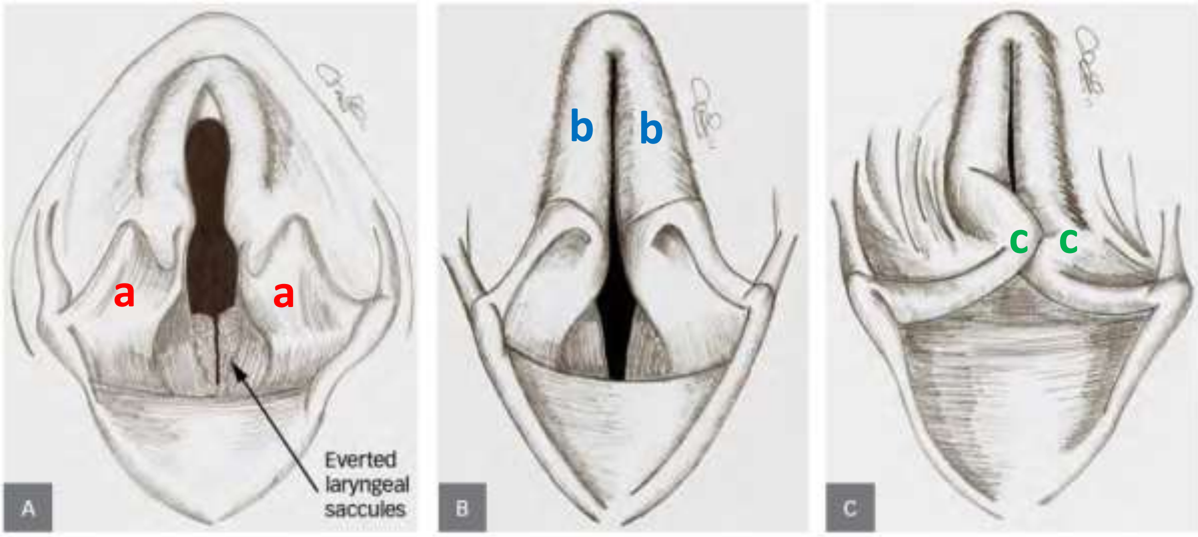


Fig. 04. (A) Stage I: Everted laryngeal saccules medial to the vocal folds. (B) Stage II: Medial collapse of the dorsal portion of the corniculate process of the arytenoids. (C) Stage III: Collapse and sometimes overlap of the more ventrally located cuneiform processes in addition to the previous stages of disease. a: Arytenoids cartilage. b: Corniculate process of the arytnoid. c: Cuneiform process (Adapted from Miller & Gannon, 2015).

Dupre (2008) reports that moderate to severe laryngeal collapse (stages II and III) is seen in 50% to 64% of dogs with BOAS.

Bronchial collapse has been reported in brachycephalic dogs, and the severity of the collapse was correlated with the presence of laryngeal collapse (De Lorenzi, Bertoncello & Drigo, 2009). It was believed that repeated increases in subatmospheric pleural pressure may lead to degenerative weakening of the lower airways but it is uncertain whether an inflammatory process rather than a mechanical process may be at least partially responsible for airway weakening (Mellema & Guilaume, 2015).

3.0 CLINICAL SIGNS

Clinical signs associated along the URT can be dynamic or static (Clarke, 2015). Dynamic signs occur during inspiration or expiration, and depend on the location of the obstruction, stress or anxiety, and the degree of alteration on the airway dynamics (Clarke, 2015). Static signs occur with fixed extraluminal or intraluminal obstructions (Clarke, 2015).

The clinical signs are usually respiratory signs that may vary with the degree of obstruction (Brown & Gregory, 2005). The most common signs of BOAS are snoring and stertorous breathing, stridor, exercise intolerance, tendency to overheating, inspiratory dyspnoea and increased respiratory effort, inability to breathe comfortably when not panting, and, in severe cases cyanosis and collapse may occur (Lodato & Hedlund, 2012; Dupre, 2008; Clarke, 2015).

Koch *et* al (2003) report that when the URT is obstructed, an inspiratory stridor is the dominant clinical sign and the stridorous breathing is usually associated with a narrowing in the upper airway, such as laryngeal collapse (Riecks, Birchard & Stephens, 2007).

A stertourous breathing is characterized by a low-pitched snoring like inspiratory and/or expiratory noise associated with excessive tissue in the upper airway (Clarke, 2015). Stertor (snoring) was the most common clinical sign (58.1%) in Riecks, Birchard & Stephens (2007) study.

Hedlund (2007) includes as increased inspiratory effort signs the retraction of the lip commissures, open mouth breathing or constant panting, forelimb abduction and exaggerated use of abdominal muscles. Packer, Hendricks, Tivers & Burn (2015) mention that severely affected dogs develop a laboured breathing, adopting a wide stance with their elbows abducted from their chest, use of accessory abdominal musculatures and over insufflation of the chest. In addition, a paradoxical movement of the thorax and abdomen with recruitment of accessory respiratory muscles, inward collapse of the intercostal spaces and thoracic inlet, and orthopneic postures (extended head and neck, with reluctance to lie down) may be apparent (Hedlund, 2007).

Lodato and Hedlund (2012) categorized the respiratory signs in mild, moderate or severe. Animals with mild respiratory signs have pink mucous membranes, normal attitude and normal posture. Animals with moderate respiratory signs have pink mucous membranes, are anxious, restlessness and occasionally demonstrate abducted elbows. Animals with severe respiratory signs have pale or cyanotic mucous membranes, can be disoriented or semicomatose, and have abducted elbows and generalized use of accessory abdominal musculature.

Another common sign is hyperthermia due to an increased work from the respiratory muscles, which generates a greater amount of heat (Reiter & Holt, 2012). Also an inefficient respiration impairs the cooling ability of the animal making then prone to heat stress (Lodato & Hedlund, 2012).

3.1 GASTROINTESTINAL SIGNS

In some animals, gastrointestinal (GI) signs may be present, such as gaging, salivation, retching, regurgitation or vomiting due to a false deglutition, which results in sudden respiratory distress (Meola, 2013; Lodato & Hedlund, 2012; Lecoindre & Richard, 2004).

Mellema & Hoareau (2015) proposed that chronic upper airway obstruction and greater subatmospheric pleural pressures may lead to gastro-oesophageal reflux, making brachycephalic dogs predisposed to regurgitation and vomiting, which are known risk factors for aspiration pneumonia. Lecoindre & Richard (2004) believe that an abnormally low negative intrathoracic pressure could be sufficient to worsen or even induce a hiatal hernia and/or gastroesophageal reflux.

Currently, the relationship between GI signs and respiratory signs of BOAS is unknown, but there is a positive correlation between the severity of GI signs and respiratory signs among dogs with BAS (Lodato & Hedlund, 2012; Poncet *et al*, 2006).

There are a few hypotheses that try to correlate the respiratory signs and the GI signs. Dupre (2008) says that the respiratory distress could stimulate the autonomous sympathetic nervous system, which would slow gastric motility and increase the gastric emptying time.

Lecoindre & Richard (2004) say that the aerophagia, which is common in BAS, leads to chronic dilation of the stomach, and thus increased intragastric pressure, mimicking a meal. Due to this, gastrin and gastric acid are released during the absence of an effective meal. The production of mediators (cholecystokinin, secretin) is then stimulated, leading by their trophic effect to a hyperplasia of the antral and pyloric mucosa, culminating in hypertrophic antropathy. In turn, this will increase the intragastric pressure, which will delay the gastric emptying and promote the risk of gastroesophageal reflux. Indeed, in 10 cases out of 13 cases of hypertrophic antropathy, a substantial duodenogastric reflux was observed (Leocoindre & Richard, 2004).

A study with 30 brachycephalic dogs with digestive disorders (Lecoindre and Richards, 2004) found that 83% had concurrent esophagitis, being chiefly located in the distal third of the thoracic oesophagus, but could extend to the whole thoracic oesophagus. In the same study, 16 cases of peptic esophagitis were associated with sliding hiatal hernia, which aggravated the frequency of the gastroesophageal reflux.

In Poncet *et al* (2005) with 73 brachycephalic dogs that presented with URT signs, 97.2% had abnormalities in their oesophagus (esophagitis, hiatal hernia, gastroesophageal reflux), stomach (pyloric hyperplasia, atresia gastritis, duodenogastric reflux) or duodenum (duodenitis). Another study (Poncet *et al*, 2006) found that 98% of examined brachycephalic dogs with BAS had histologic evidence of chronic gastritis.

Poncet *et al* (2006) reports no correlation between GI signs and respiratory signs in any breeds. In contrast, in Haimel and Dupre study (2015) indicate that the GI signs are more frequent and more severe in French bulldogs than Pugs with similar grades of respiratory signs.

4.0 DIAGNOSTIC

The diagnosis of BOAS is made based on signalment (breed and age), history and clinical signs, and a good physical examination (Clarke, 2015). An early diagnosis and surgical intervention is imperative to improve airflow and minimize or prevent the progression of secondary changes (Lodato & Hedlund, 2012).

The primary diagnostic tool is a good physical exam and history. Animals with BOAS usually have a typical history and supportive physical examination, but in some cases the animals may not show any respiratory effort or distress on examination, in which case the owner's description becomes very valuable (Moores & Anderson, 2010).

The physical examination should start with the size observation of the nares (Fig. 05) and breathing, auscultation of the larynx for stertor and stridor, palpation of the trachea, thoracic auscultation, and temperature measurement (Reiter & Holt, 2012). This should be followed by oral examination, which often requires a sedation or light anaesthesia (Brown & Gregory, 2005). The oral examination includes assessment of the length and appearance of the soft palate, size and shape of the rima glottis, and presence or absence of laryngeal saccule eversion or laryngeal collapse (Clarke, 2015).

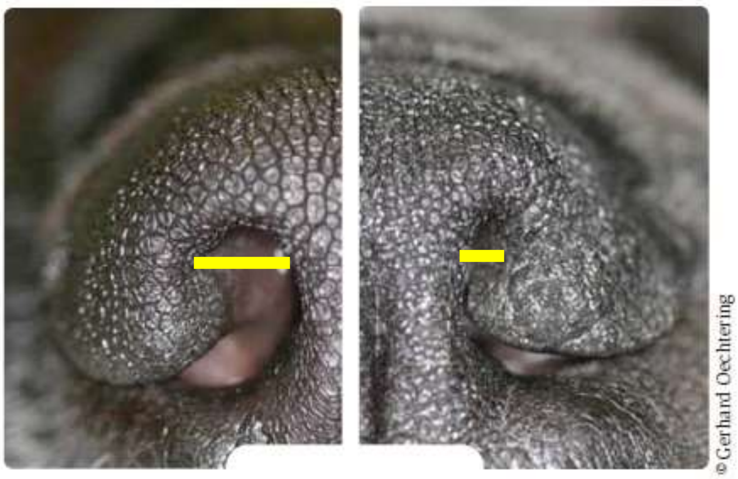


Fig. 05. Distinction between a normal size nostril (left) and a stenotic nostril from a brachycephalic dog. Yellow bar show the size difference of the nostrils opening. (Adapted from Oechtering, 2010).

Auscultation of the lung and heart sounds may be complicated due to enhanced sounds from the upper airways (Moores & Anderson, 2010). The greatest airway noise is usually noticed in the larynx (Monnet, 2006).

Concurrent cardiac disease with associated heart murmurs, such as congenital pulmonic stenosis, may be found as Bulldogs are particularly prone (Reiter & Holt, 2012).

Blood gas analysis or pulse oximetry are important to determine the need of oxygen supplementation (Lodato & Hedlund, 2012). Bicarbonate levels, pH and partial pressure of carbon dioxide in a venous sample or a pulse oximetry may be normal in a stable patient, but in collapse animal oxygen saturation may be below 80% which requires urgent oxygen support (Lodato & Hedlund, 2012).

A study conducted by Hoareau, Jourdan, Mellema & Verwaerde (2012) concluded that brachycephalic dogs have a lower arterial partial pressures in oxygen (PaO_2) with normal alveolar-to-arterial gradient, a higher arterial partial pressure of carbon dioxide ($PaCO_2$) and a higher packed cell volume (PCV) and hemoglobin concentrations when compared with non-brachycephalic dogs. According to Mellema & Hoareau (2015) brachycephalic dogs may reset their chemoreceptor threshold and tolerate a lower PaO_2 and higher $PaCO_2$ without sensing the drive for increasing ventilation, this phenomenon is called "habituation". The higher PCV and hemoglobin are thought to be a compensatory mechanism to maintain normal arterial percentage of oxygen (Hoareau, Jourdan, Mellema & Verwaerde, 2012).

Anaesthesia of a brachycephalic dog is challenging as most anaesthetic drugs lead to relaxation the muscles of the URT. However the diaphragm is still able to produce negative pressure thus promoting collapse of the upper airway soft tissue (Koch *et al*, 2003). As the anaesthetic risk is high in these animals, it is often recommended to proceed with the surgical procedure immediately after the pharyngoscopy and laryngoscopy (Lodato & Hedlund, 2012).

4.1 DIAGNOSTIC: STENOTIC NARES AND BREATHING

The stenotic nares are easily diagnosed with visual assessment of the malformed dorsolateral cartilages during physical examination (Hendricks, 2004).

A nonspecific signs of increased upper airway resistance is open mouth breathing, which is a behavioural adjustment that increases the oropharyngeal lumen to compensate for the narrow airways (Hendricks, 2004).

Mucous membrane colour, general posture and attitude, respiratory pattern, retraction of the lip commissures, elbow abduction and use of accessory respiratory muscles can be assessed to determine an increase respiratory effort (Lodato & Hedlund, 2012; Hedlund, 2007).

4.2 DIAGNOSTIC: SOFT PALATE

As mentioned before, the soft palate assessment requires sedation or light anaesthesia. To assess the soft palate a laryngoscope is required to depress the back of the tongue to facilitate the view. The tonsillar crypts, epiglottis and, length and appearance, of the soft palate, should be assessed (Clarke, 2015).

In a normal dog, the tip of the soft palate ends slightly rostrally to the tip of the epiglottis (Meola, 2013). In a brachycephalic dog, the tip of the soft palate can often be seen vibrating and covering the epiglottis completely and may even be sucked by the glottis (Brown & Gregory, 2005; Moores & Anderson, 2010).

An elongated soft palate is one that extends more than 1 to 3 mm caudal to the tip of the epiglottis, preventing the ventral displacement of the epiglottis (Hedlund, 2007).

Moores & Anderson (2010) suggest that to avoid anaesthesia in these patients, the soft palate can be assessed by fluoroscopy, or by an accurately positioned lateral skull radiograph.

Lateral radiographs of the skull and cervical regions can be used to assess the length of the soft palate and the overlap with the tip of the epiglottis (Brown & Gregory, 2005). Thoracic radiographs are also recommend to evaluate for lower airway disease for aspiration pneumonia and non-cardiogenic pulmonary oedema, it also allows to measure the size of the trachea, and diagnose tracheal hypoplasia, and cardiac silhouette abnormalities (Brown & Gregory, 2005; Lodato & Hedlund, 2012).

4.3 DIAGNOSTIC: LARYNGEAL SACCULES EVERSION

After the soft palate assessment and before intubation of the animal, the laryngeal saccules must be checked (Brown & Gregory, 2005). The laryngeal examination is often hampered by the long soft palate, but can be achieved by use of a long laryngoscope to gently lower the epiglottis ventrally and a second laryngoscope or wooden tongue depressor to lift the palate dorsally (Moores & Anderson, 2010).

The laryngeal saccules are not normally seen (Brown & Gregory, 2005). When everted, the laryngeal saccules appear as a tissue mass rostrally, obscuring the vocal cords (Brown & Gregory, 2005).

Acutely everted saccules are often pale or white, shining and oedematous, while chronically everted saccules are more likely to be pink or red and fleshy in appearance (Hedlund, 1996 in Brown & Gregory 2005).

4.4 DIAGNOSTIC: LARYGEAL COLLAPSE

Similarly to the laryngeal saccules eversion assessment, the diagnosis of laryngeal collapse is made by direct visualization with a laryngoscope or transoral endoscopy and prior to intubation of the induced animal (Brown & Gregory, 2005). An assistant is essential for a correct evaluation of laryngeal collapse. The indication of the phases of respiration during laryngeal exam is imperative to confirm appropriate laryngeal motion and rule out paradoxical motion, which can be confused as normal laryngeal function in dogs with laryngeal paralysis (Clarke, 2015). Paradoxical motion is defined as inward movement of the arytenoids secondary to negative pressure generated upon inspiration (Clarke, 2015).

The laryngeal cartilages must be assessed for oedema, inflammation, ability to abduct, proliferative abnormalities, rima glottis diameter, eversion of laryngeal saccules and position (Brown & Gregory, 2005; Clarke, 2015). The vocal cords are not usually seen in an animal with laryngeal collapse, due to the medial dislocation of the corniculate process and cuneiform process of the arytenoid cartilage (Brown & Gregory, 2005).

The BSAVA classified the collapse as mild (Stage I) if only everted laryngeal saccules are present, moderate (Stage II) if a distinct rima glottis is still visible, and severe (Stage III) when the glottis is only visible as a slit between the collapsed arytenoids processes. A more detailed description of the stages of laryngeal collapse can be found at *Secondary Change: Laryngeal Collapse* section.

Endoscopy visualization is the best mean to identify BAS abnormalities – elongated soft palate, everted laryngeal saccules, laryngeal collapse, everted tonsils and nasopharyngeal turbinates can all be diagnosed endoscopically (Lodato & Hedlund, 2012). During the same anaesthetic an upper gastro-intestinal endoscopy is usually recommended if GI signs are present (Dupre, 2008).

Bernaerts *et al* (2010) study found that 70% of dogs with BAS had a partial collapse of the left mainstem bronchus, this finding has not been previously described as a component of BOAS. The authors believes that this collapse of the left main bronchus is probably an secondary change due to the increase in negative pressure, but further studies are needed to confirm that theory.

After assessing the animal with the endoscope, a bronchoalveolar lavage (BAL) should be performed if there is radiographic evidence or clinical signs of aspiration pneumonia (Reiter & Holt, 2012). The fluid samples are evaluated cytologically, and submitted for bacterial culture and sensitivity testing (Reiter & Holt, 2012).

4.5 DIAGNOSTIC: HYPOPLASTIC TRACHEA AND TRACHEAL COLLAPSE

Thoracic radiographs are helpful to evaluate for tracheal hypoplasia, tracheal collapse, hiatal hernia and aspiration pneumonia (Clarke, 2015).

To diagnose tracheal hypoplasia, the tracheal diameter is measured at the thoracic inlet and expressed as a percentage or ratio of the thoracic inlet height (Reiter & Holt, 2012). A hypoplastic trachea is defined as a ratio of less than 0.13 for bulldogs and 0.16 for other brachycephalic breeds (Miller & Gannon, 2015). It must always be taken into count that during active airway infection, such as bronchopneumonia, the trachea may be inflamed and oedematous, which can lead to misdiagnosed tracheal hypoplasia (Clarke, 2015).

It is important to take into count that tracheal collapse have a dynamic and static component – this means that in a radiograph we can only identify the static component (Lodato & Hedlund, 2012). Tracheal collapse is best identified in the cervical area during inspiration and in the intrathoracic area during exhalation therefore real time imaging, such as endoscopy or fluoroscopy, is the best mean to diagnose tracheal collapse (Deweese & Tobias, 2014; Lodato & Hedlund, 2012).

A grading system to document the severity of a tracheal collapse was created by Dr. Tangner and Dr. Hobson in 1982 to aid in determining the best way to treat the collapse (Deweese & Tobias, 2014). There are four stages of collapse: A grade I classification is characterised by a 25% or less occlusion of the tracheal lumen. Grade II is 25 to 50%, grade III 50 to 75% and grade IV is 75 to 100% (Deweese & Tobias, 2014).

5.0 SURGICAL TREATMENT

Additional conditions may be present at the time of diagnosis therefore a good preoperative analysis is imperative (Hendricks, 2004). Brachycephalic breeds clinically affected with BAS are also commonly afflicted by unrelated conditions that should be assessed as part of a complete evaluation before the surgery (e.g., skin and ophthalmologic disease, dental and musculoskeletal abnormalities) (Hendricks, 2004).

Respiratory difficulty leads to aerophagia, and the pressure changes may lead to hiatal hernias and aspiration pneumonia that must be assessed prior to the surgical procedure (Hendricks, 2004).

One important fact to take in count before the surgery is that these patients are at a relatively high anaesthetic risk (Mercurio, 2011). The respiratory compromise and an associated increase in vagal tone make then prone to bradyarrythmias intraoperatively (Mercurio, 2011).

Owners must always be aware of the perioperative risks associated with the airway surgery and anaesthesia (Mercurio, 2011).

5.1 STENOTIC NARES - RHINOPLASTY

The correction of the stenotic nares is the most important aspect for BOAS surgery as narrow nasal passageways increase significantly the airflow resistance (up to 80%) which can lead to secondary changes (Clarke, 2015). All of the different surgical techniques aim to open the lateral wings of the nostrils, which will improve the nasal air flow (Dupre, 2008).

It is recommended to perform rhinoplasty in puppies with BOAS at 3 to 4 months of age to prevent progression and thus secondary changes, such as laryngeal collapse or pharyngeal oedema (Koch *et al,* 2003). Trappler & Moore (2011) are the opinion that general practitioners, who are comfortable with the procedures, should offer correction of the nares and an elongate soft palate the time of castration.

There are multiple rhinoplasty techniques available, and they can be performed with scalpel blade, laser or electrosurgery. With the use of a scalpel blade the haemorrhage is controlled by direct local pressure and closure is performed with a 4-0 or 5-0 monofilament suture with a simple interrupted suture pattern (Schmiedt & Creedy, 2012). With the use of laser or electrocautery, the haemorrhage is reduced compared to the use of scalpel blade, however an improper use of these techniques may increase tissue damage prolonging wound healing and creating depigmented scar tissue (Schmiedt & Creedy, 2012).

BAS has been a recognised disorder for many years. Amputation of the alae was the first surgical procedure to be described, in 1949 by Trader (Trappler & Moore, 2011).

Huck, Stanley & Hauptman study (2008) revisited this technique, which showed excellent functional and cosmetic results in immature Shih Tzu puppies (less than 6 months). Long term follow up (12 months) showed complete resolution of the clinical signs associated with stenotic nares and superior cosmetic results when compared with wedge resection technique. However, haemorrhage may be more significant because the wounds are not closed surgically and until the healing process is complete, the wound may not be considered aesthetically pleasing. The author recommend considering surgical amputation of the alae, Trader technique, as a treatment option for immature Shih Tzu with bilateral stenotic nares.

In attempt to improve the cosmetic appearance of the surgical procedure of amputation of the alae, various wedge resection techniques have been described for either narrowing, lifting or creating caudal traction on the alae in order to increase the air inflow thought the nostrils (Ellison, 2004). Wedge resection techniques involve the removal of a pyramid shaped section of the external nares in a vertical, horizontal or lateral plane, depending on the technique (Hedlund, 2007).

Trappler & Moore (2011) differentiated the three wedge resection techniques in a simple way. In the vertical resection the apex of the wedge is at the dorsalmost aspect of the wing of the alae. In the horizontal resection the wedge has a medial to lateral direction, ending just dorsal to the mucosal edge of the nares. The lateral resection involves removal of the caudolateral edge of the nares and the adjacent skin. Regardless of the wedge resection technique, the incidence of postoperative complications is low (Brown & Gregory, 2005).

The length of the base of the wedge determinates the degree of opening of the nares (Trappler & Moore, 2011). Regardless the technique chosen both incisions must meet at the alar cartilage, creating the depth of the wedge (Trappler & Moore, 2011).

Alapexy is a different technique for repairing stenotic nares describe by Ellison (2004) (Fig. 06). It involves the creation of two elliptical incisions, one in the ventrolateral alar skin and one in the adjacent pigmented skin, just 3 to 5 mm apart. These two incisions are apposed, pulling the alae laterally and caudally, and the alae are anchored to the adjacent skin using a two-layer closure technique. This means that the nasal alae are permanently fixed in an abducted position. The author reports that the success rates for alapexy technique is similar to the wedge resection technique, although it involves more suturing and potentially longer surgical times therefore it should be reserved for cases where the simpler techniques have failed or in dogs with severe stenosis that are believed to be at high risk for failure. Trappler & Moore (2011) believe that alapexy is a good alternative for patients with excessive flaccidity of the alar cartilage, or if the others techniques have failed.

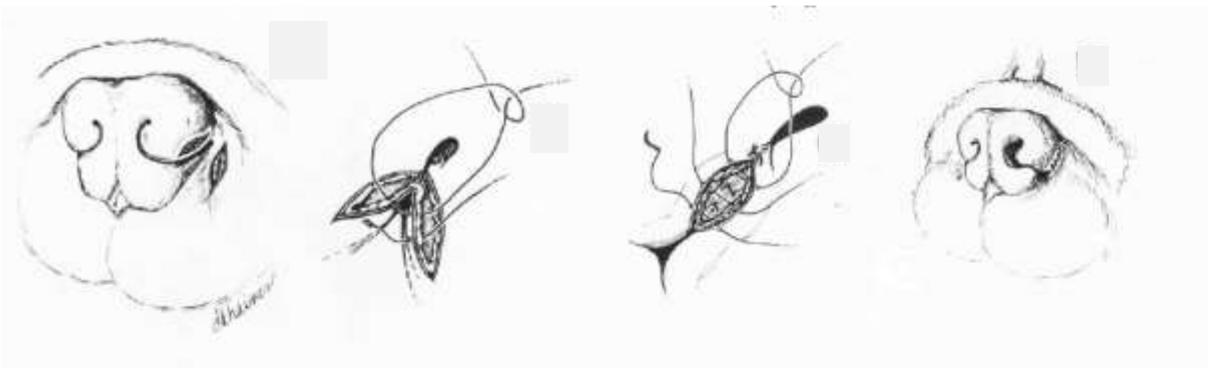


Fig. 06. Alapexy procedure. (Adapted from Ellison, 2004)

Regardless of the technique the patient is placed in a perfect and symmetrical sternal recumbency (Schmiedt & Creedy, 2012). Hedlund (2007) says that the planum nasale should be gently prepped with antiseptic soap and scrub solution.

As it was previously mentioned, Oechtering (2010) considers a new anatomical component in BOAS – stenosis of the nasal vestibule caused by the inner part of the nasal wing. The author explains that unlike humans, the nasal vestibule in dogs is not empty, it is filled to a large extent by the voluminous, caudally extending nasal wing, which then merges into the alar fold. The ala is too large for the nose, and presses against the septum from the lateral aspect (Figure

02) (Oechtering, 2010). In conclusion, the nasal wing consists in the visible outer part and an inner part which is invisible from the outside (Oechtering, 2010). This type of obstruction is not correct by the wedge resection technique and therefore the therapeutic solution is a nasal vestibuloplasty (Oechtering, 2010).

5.2 SOFT PALATE - PALATOPLASTY

The aim of palatoplasty is to shorten the soft palate, usually to the level of the caudal border of the tonsillar crypt, allowing a normal opening of the epiglottis (Brown & Gregory, 2005). There are different techniques described such as sharp dissection, diode laser, electrocautery and carbon dioxide laser surgery. Despite the technique chosen, it is important to minimize tissue trauma, which can result in pharyngeal swelling, airway obstruction, and haemorrhage (Brown & Gregory, 2005).

A review study in dogs affected with BAS by Harvey in 1982 and Lorison *et* al in 1997 indicated that those in which the stenotic nares were enlarged surgically in addition to soft palate resection had a more favourable outcome than dogs treated by soft palate resection alone (Brown & Gregory, 2005).

The dog is positioned in sternal recumbency with the upper jaw suspended by a gaze placed around the maxillary canine teeth, and the assessment of the soft palate must be made in a neutral position without an endotracheal tube present (Reiter & Holt, 2012). Gauze should be placed around the endotracheal tube at the level of the glottis to prevent blood leakage to the airways (Hedlund, 2007).

The surgeon must carefully assess the amount of soft palate to be removed before any other procedures, such as removal of everted laryngeal saccules (Lodato & Hedlund, 2012). Removal of too little soft palate will lead to suboptimal results and removal of too much soft palate will lead to nasopharyngeal reflux of food during eating, predisposing the dog to serious complications, such as aspiration pneumonia (Brown & Gregory, 2005). Trappler & Moore (2011) suggest that the removal of too little tissue is preferred over removal of too much tissue because patients can undergo further surgery to correct a persistently long palate.

The tip of the epiglottis and middle to caudal third of the tonsillar crypt are used as the landmarks for incision placement in the soft palate (Lodato & Hedlund, 2012). Reiter & Holt (2012) describe the caudal border of the palatine tonsils as their soft palate resection landmark, which must be assessed with minimal retraction of the tongue and palate.

In the conventional soft palate resection the excision is made with a scalpel blade or Metzenbaum scissors and the apposition of the oropharyngeal and nasopharyngeal mucosa is made with a monofilament absorbable suture using a simple continuous suture pattern

(Trappler & Moore, 2011). The use of electrocautery has been showed to cause excessive postoperative oedema and it not recommended (Hedlund, 2007).

Davidson, Davis, Campbell, Williamson, Payton, Healey & Bartels (2001) believe that the carbon dioxide laser offers an alternative method of soft palate resection that can minimize, or even avoid, swelling and oedema, reducing the postoperative risk in these patients. The carbon dioxide laser efficiently vaporizes and excises epithelial and mucosal tissue and provides good haemostasis in tissues with high capillary density (Davidson *et al*, 2001).

Davidson *et al* (2001) compared sharp dissection with use of a carbon dioxide laser and they found similar clinical outcomes for both techniques. The mean surgical time for the laser (309 seconds) was shorter than for the sharp dissection (704 seconds). The healing time was around 14 days for both techniques. Beyond the shorter surgical time, laser has others advantages, such as reduced haemorrhage, swelling and postoperative pain (Trappler & Moore, 2011). Davidson *et al* (2001) concluded that the laser advantages are related to its coagulation properties, sealing of small blood vessels, lymphatics and nerve endings. However, this study was performed in non-clinical affected brachycephalic dogs that did not suffer from URT disorder, therefore the clinical signs directly attributable to the procedure could be separate and irrelevant to clinical status prior to surgery (Davidson *et al*, 2001).

Dunié-Merigot, Bouvy & Poncet (2010) compared carbon dioxide laser, electrocautery and diode laser for resection of the soft palate. The proportion of dogs with favourable outcome was significantly higher in the carbon dioxide group and electrocautery group. This study concluded that the carbon dioxide laser appears to have many advantages over the diode laser or electrocautery in the short-term follow-up (6 months); surgical time was shorter, and the need for an additional sealing device was less frequent, suggesting that bleeding is less common with carbon dioxide laser. Early complications were greater in the diode group, which included two dogs that died and two that required a tracheostomy.

After palatoplasty, mild postoperative complications can occur, such as coughing, regurgitation or gagging which can be present for several days (Brown & Gregory, 2005). Occasional regurgitation of saliva with strains of blood is expected (Brown & Gregory, 2005). Severe postoperative complications include dyspnoea and cyanosis due to upper airway obstruction and death by aspiration pneumonia or failure to recover from anaesthesia (Reiter & Holt, 2012).

Dupre (2008) describes a new palatoplasty technique, folded flap palatoplasty, which is used to address pharyngeal and laryngeal obstruction. This technique achieves a reduction of the soft palate thickness and length, thereby relieving the nasopharynx and oropharynx obstruction. This technique, in combination with surgery for stenotic nares, was shown to be safe and effective in a retrospective study of 55 dogs (Findji & Dupre, 2008).

5.3 ABNORMAL NASOPHARYNGEAL TURBINATES - TURBINECTOMY

The intra-nasal obstruction by hyperplastic turbinates can be alleviated by laser-assisted turbinectomy, which is performed with an endoscopic laser (Lodato & Hedlund, 2012; Dupre, 2008). The goal of this procedure is to reduce the airflow resistance through removal of excise aberrant tissue (Lodato & Hedlund, 2012). Turbinectomy is a long and tedious procedure, and unfortunately there is potential for re-growth (Lodato & Hedlund, 2012).

5.4 LARYNGEAL SACCULES EVERSION - SACCULECTOMY

In most cases, BAS is treated from “front to back”, this means that the surgical procedure begins with the stenotic nares, then soft palate, and if necessary resection of the laryngeal saccules (Brown & Gregory, 2005). It is widely accepted that the excision of the everted saccules leads to an immediate enlargement of the rima glottis improving the respiratory function in the immediate postoperative (White, 2012).

Resection of the everted laryngeal saccules is reported to be a quick and simple procedure and is used by the majority of surgeons (Brown & Gregory, 2005). There are other techniques, such as electroscalpel or laryngeal cup forceps, but these are associated with greater tissue trauma, and with that a greater risk of postoperative complications (Brown & Gregory, 2005). More recently the need for resection of the everted laryngeal saccules has been questioned as described below.

Trappler & Moore (2011) recommend visualization and resection by pushing the endotracheal tube to one side, although that can also be achieved with temporary extubation or temporary tracheostomy. Once the saccules are visualized, they can be grasped with a long haemostats or Allis tissue forceps, retracted rostrally, and excised with a Metzenbaum scissors or a scalpel blade (Trappler & Moore, 2011). Haemorrhage is usually minimal and can be controlled with gentle pressure (Hedlund, 2007).

A recent prospective study undertaken by Cantatore, Gobbetti, Romussi, Brambilla, Giudice, Grieco & Stefanello (2012) assessed the surgical outcome following laryngeal saccule resection in ten brachycephalic dogs. The authors hypothesised that the reduction of airflow turbulence might allow the spontaneous reduction of the saccule into his ventricle, thus supporting the idea that resection is not always necessary. The surgical procedure included vertical wedge resection rhinoplasty and staphylectomy. In each patient only the left everted saccule was resected, leaving the right one untouched and used as a control. Visual examination of the larynx was undertaken two to four months postoperatively, and, in all cases, there was no evidence of a spontaneous resolution of the right sided saccule eversion (Cantatore *et al*, 2012). The authors concluded that there was no advantage from leaving everted saccules intact since the unlikeliness of a spontaneous resolution of this secondary change.

5.5 LARYNGEAL COLLAPSE – ARYTENOID LATERALISATION

Unfortunately, in most of the cases, laryngeal collapse is generally treated conservatively (Brown & Gregory, 2005; Moores & Anderson, 2010). The management consists in revision of the previous procedures (stenotic nares correction, soft palate correction, laryngeal saccules removal (Brown & Gregory, 2005). Dupre (2008) also agrees that the relief of the proximal airway obstruction alleviate the signs of laryngeal collapse as laryngeal collapse and saccule eversion are secondary events due to increase respiratory depression. Corticosteroid administration is recommended by some studies (Brown & Gregory, 2005).

Surgical treatment for laryngeal collapse is still under debate. All surgical procedures for laryngeal collapse aim to alleviate the upper airway obstruction by relocating or removing the obstructing laryngeal tissue (Mercurio, 2011). Poncet *et al* (2006) believes that when the arytenoid cartilages are abnormally flaccid, unilateral arytenoid lateralisation is ineffective since upon inspiration the dorsal border of the corniculate cartilage still rolls into the glottis lumen.

The unilateral arytenoid lateralisation (UAL) involves the fixation of the arytenoid cartilage to the thyroid or cricoid cartilage using a non-absorbable suture material (Mercurio, 2011). Despite being accept by many surgeons as the treatment of choice, the UAL is associated with high complication rates of 10% to 58% (Mercurio, 2011). The most common complication following UAL is aspiration pneumonia, occurring in 18 to 28% of dogs after surgery (Mercurio, 2011).

Historically, advanced stages of laryngeal collapse have been associated with a poorer prognosis, and permanent tracheostomy is recommended as a last resource procedure (Hedlund, 2007; Monnet, 2006; Koch, 2003). Recent studies have reported a marked improvement to standard BOAS surgery despite advanced stages of laryngeal collapse (Poncet *et al,* 2006; De Lorenzi *et al*, 2009). Haimel and Dupre (2015) believes that although the severity of laryngeal collapse may be associated with age, animals with advanced grades of laryngeal collapse still benefit from surgery. Permanent tracheostomy is the recommended procedure for severe laryngeal collapse that has not responded to all other corrective techniques as it bypasses the upper airways and allows for relief of dyspnoea (Trappler & Moore, 2011); it should be considered the last resource of surgical option, this is because the high risk complications such as recurrent lower airway infection (Mellema & Hoareau, 2015).

In addition to the surgical procedures described, some surgeons recommend and perform additional procedures to reduce the amount of redundant tissue in the pharynx, these include tonsillectomy and removal of others folds of redundant pharyngeal tissue, but the effectiveness of these techniques is unproven, and most surgeons do not perform them (Brown & Gregory, 2005).

One important fact to take in count before the surgical procedure is that these patients are at a relatively high anaesthetic risk (Mercurio, 2011). The respiratory compromise and an associated increase in vagal tone make them prone to bradyarrythmias intraoperatively (Mercurio, 2011).

Owners must always be aware of the perioperative risks associated with the airway surgery and anaesthesia (Mercurio, 2011). Patients with GI signs should receive adequate medical treatment before or in combination with the BOAS surgery to improve prognosis and decrease the risk of complications (Mercurio, 2011).

6.0 POSTOPERATIVE CARE

The brachycephalic patient has a higher risk of airway obstruction on extubation (Mellema & Hoareau, 2015) due to the disease itself. In addition, the prolonged transoral endotracheal intubation, required for anaesthesia, promotes oral, pharyngeal and laryngeal oedema, and oropharyngeal inspiratory muscle weakness, which further increases the airflow resistance (Mellema & Hoareau, 2015). For these reasons recovery must be slow and quiet, and the endotracheal tube must be left in place for as long as the dog tolerates it (Moores & Anderson, 2010). That is also the reason why some brachycephalic dogs have minimal clinical signs until they are recovering from anaesthesia and surgery for another condition (Reiter & Holt, 2012).

Postoperatively, close monitoring is important due to a possible obstruction of the larynx and trachea caused by inflammation or bleeding (Lodato & Hedlung, 2012). Airway swelling, decreased pharyngeal reflexes, hyperthermia, and the increased risk of aspiration requires close patient monitoring for at least 24 to 48 hours postoperatively (Trappler & Moore, 2011).

Steroids can be used at anti-inflammatory doses postoperatively to reduce swelling, but no controlled study has evaluated their effects on outcome (Mellema & Hoareau, 2015). Even so Koch *et al* (2003) believes that short-acting steroids may help prevent life-threatening postoperative swelling resulting from intubation and surgical manipulation. Prednisolone (0.5 to 1.0 mg/kg IV or PO) may be used to help decrease airway swelling (Trappler & Moore, 2011). Prednisolone is preferred over dexamethasone sodium phosphate when multiple doses are to be administered (Trappler & Moore, 2011). NSAIDs are not commonly administered due to its potential GI effects in already predisposed patients (Trappler & Moore, 2011).

The respiration rate and effort, as well as arterial haemoglobin oxygen saturation must be frequently monitored to assess the ventilation capacity (Reiter & Holt, 2012). Supplemental oxygen may also be provided, by non-stressful techniques such as oxygen cage (Trappler & Moore, 2011). In addition, the animal should be monitored for gagging, retching or vomiting and thoracic auscultation and temperature assessed periodically (Reiter & Holt, 2012).

In stressed and anxious patients sedation with butorphanol (0.2 to 0.4 mg/kg), acepromazine (0.02 mg/kg) or diazepam (0.2 mg/kg) may be beneficial (Lodato & Hedlund, 2012).

Food and water should be withdrawal for 12 to 24 hours and after that period a small amount of food can be offered under supervision (Reiter & Holt, 2012). The diet should consist of only soft food for 10 to 14 days, to minimize irritation of the upper airway (Trappler & Moore, 2011). Hedlund (2007) reports that hand-feeding of soft meatballs of humid food helps to slow ingestion and prevent dysphagia.

Many dogs with BOAS have concurrent GI disorders that must receive treatment, which includes H_2 blockers, proton pump inhibitors, prokinetics, antibiotics, antacids and steroids (Lodato & Hedlund, 2012).

Perioperative metoclopramide may help to reduce the frequency of postoperative vomiting and regurgitation, being indicated to all BOAS dogs and not only dogs with GI signs (Trappler & Moore, 2011).

Severe postoperative complications include airway swelling, vomiting, regurgitation and aspiration (Riecks, Birchard & Stephens, 2007). Other less severe complications reported include dehiscence of the nares, persistent upper airway stertor/stridor, recurrence of less extreme upper airway signs, and voice change (Riecks, Birchard & Stephens, 2007). According to Haimel and Dupre (2015) the most frequent postoperative complications reported were dyspnoea (22.2%), vomiting (16.7%), nasal discharge (15.3%) and regurgitation (13.9%). The least frequent were coughing (2.8%), hyperthermia (2.8%) and pneumonia (4.2%). In the great majority of cases, the postoperative mortality rate is associated with obstruction secondary to upper airway swelling or aspiration pneumonia (Trappler & Moore, 2011).

Dyspnoea was also reported the most common postoperative complication by Mercurio (2011) which was thought to be due to pharyngeal and laryngeal secondary oedema and inflammation alongside worsening of the laryngeal collapse associated with the reduced pharyngeal and laryngeal muscle tone secondary to anaesthesia.

Client education is essential for a good long-term care, being extremely important in the first two weeks (Trappler & Moore, 2011). Owners must be advised to keep the dog in cool environment, allow only moderate levels of activity, and to use a harness instead of a collar and keep animals in a lean body condition (Trappler & Moore, 2011).

7.0 PROGNOSIS

The prognosis depends on a number of factors, such as the severity of airway pathology, patient temperament, surgical repair, and whether a temporary tracheostomy is required in the postoperative period (Trappler & Moore, 2011).

The general prognosis is good, but unfortunately with most surgical techniques the soft palate resection procedure does not have an effect on the redundant pharyngeal folds and thickness (Moores & Anderson, 2010). This means that the pharynx may continue to look very narrow despite palatoplasty (Moores & Anderson, 2010).

In this setting, the folded flap palatoplasty is recommended in dogs with a severely thick soft palate, which will relieve the obstruction in the nasopharynx and oropharynx (Dupre, 2008).

Most dogs with BOAS show improvement in both respiratory and GI clinical signs in the immediate postoperative as proved by many studies. Poncet *et al* (2006) concluded that surgical treatment of respiratory disease improves significantly, in 81% of dogs, the digestive signs immediately after surgery. In the same study, where a control gastro-oesophageal endoscopy could be obtained 6 months after the surgical procedure, a complete resolution of the gastro-oesophageal endoscopic and histopathologic signs was seen all of the time, which supports the hypothesis of a common pathophysiological pathway for URT and upper gastro-oesophageal disease in brachycephalic dogs. Lecoindre & Richards (2004) believe that the disappearance of digestive symptoms was associated with the disappearance of esophagitis lesions, with a functional improvement in the esophagogastric junction and with a decrease in the hyperplastic aspect of the antropyloric mucosa.

8.0 MEDICAL MANAGEMENT

Medical management of BAS includes weight loss, control of excitement and activity triggers, medical treatment of GI signs, and if present, treatment for pulmonary parenchymal disease (Clarke, 2015).

The medical management for BOAS, is very limited and aims to decrease the airway turbulence and the resulting inflammation and oedema (Lodato & Hedlund, 2012). For patients with BAS, stress must be minimized, a cool environment supplied, exercise restriction and weight loss in overweight patients is imperative (Lodato & Hedlund, 2012).

In animals with severe signs of respiratory distress oxygen must be supply, if dyspnoea is not resolved an emergency tracheostomy is indicated (Lodato & Hedlund, 2012).

A single dose of short-acting anti-inflammatory glucocorticoid, such as dexamethasone (0.5 to 2 mg/kg) can be beneficial to reduce airway swelling and oedema (Lodato & Hedlund, 2012).

Is important to note that prolonged medical therapy may allow progression of degenerative changes (Hedlund, 2007).

In stressed and anxious patient's sedation with butorphanol (0.2 to 0.4 mg/kg), acepromazine (0.02 mg/kg) or diazepam (0.2 mg/kg) may be beneficial (Lodato & Hedlund, 2012).

Many dogs with BOAS have concurrent GI disorders that must receive treatment, which includes H_2 blockers, proton pump inhibitors, prokinetics, antibiotics, antacids and steroids (Lodato & Hedlund, 2012).

9.0 EMERGENCY

In veterinary medicine, airway obstruction and secondary respiratory distress due to upper airway disease is a common reason for emergency patient presentation (Clarke, 2015). BAS, laryngeal paralysis and tracheal collapse are some of the underlying causes that may result in respiratory compromise from upper airway obstruction (Clarke, 2015).

Upper airway obstructive crises are not uncommon in brachycephalic dogs and acute deteriorations may manifest as acute onset or progressive worsening of respiratory distress due to a partial or complete upper airway occlusion, which can be a direct complication of BOAS (such as aspiration pneumonia) or a consequence of an anaesthetic episode (Mellema & Hoareau, 2015). A prolonged endotracheal intubation leads to local tissue oedema and oropharyngeal inspiratory muscle weakness, which further increases the airflow resistance (Mellema & Hoareau, 2015).

Brachycephalic dogs are more likely to require mechanical ventilation than non-brachycephalic dogs and aspiration pneumonia is the leading cause of respiration failure in these patients (Mellema & Hoareau, 2015).

Many unstable patients get stressed with the restrain necessary for intravenous catheter placement or other emergency diagnostics leading to stress exacerbation and oxygen demands, which will aggravate the respiratory compromise therefore the use of techniques to minimize stress are universally recommended (Clarke, 2015).

Oxygen therapy must be the first emergency care provided with the oxygen cage being the best way to provide high levels of oxygen while minimizing patient stress. Other oxygen supplementation techniques can be used, like nasal catheter, oxygen mask and flow-by oxygen. In severe situations, immediate intubation or emergency tracheostomy may be necessary life-saving interventions (Clarke, 2015).

Sedation is an important step in the management of anxious and agitated patient as it decreases inspiratory effort and reduces turbulent airflow; general anaesthesia may be needed in some cases (Mellema & Hoareau, 2015). Acepromazine is an effective anxiolytic drug however in patients with respiratory distress it is very difficult to assess the cardiovascular function and a low dose (0.005 to 0.02 mg/kg IV or 0.01 to 0.5 mg/kg IM) should be administered and repeated if needed (Clarke, 2015). Butorphanol is also a commonly used drug that provides sedation, cough suppression and analgesia with a reported dose range between 0.1 to 0.5 mg/kg IM or IV (Clarke, 2015). It is important to remember that the sedation plan should be adapted to the patient needs and circumstances and it is essential to avoid decreasing the respiratory drive of the patients as this could lead to respiratory compromise and respiratory arrest.

Hyperthermia and heat stroke are common findings in brachycephalic dogs due to the inability to increase the minute ventilation and therefore to dissipate heat (Clarke, 2015). For the reasons above, the patient should receive oxygen supplementation and be transferred to a cool and quiet environment as soon as possible and active cooling is recommended when body temperature exceeds 39.4ºC (Mellema & Hoareau, 2015). Prompt recognition and treatment of hyperthermia is imperative to prevent secondary complications such as renal, neurologic, cardiovascular and coagulation disorders (Clarke, 2015). Aspiration pneumonia is a frequent complication of BOAS, which can also cause elevated body temperature that is considered pyrexia and hyperthermia (Clarke, 2015).

For patients in whom sedation and anxiety control does not relieve respiratory distress, endotracheal intubation or, rarely, emergency tracheostomy may be required (Mellema & Hoareau, 2015; Clarke, 2015). Glucocorticoids, such as dexamethasone sodium phosphate 0.05 to 0.2 mg/kg IM, IV or SC, can be administered to reduce airway inflammation but care must be taken with hypovolemic patients and patients with a high risk of GI ulceration (Clarke, 2015).

Animals with severe and acute upper airway obstructions are at risk of developing noncardiogenic pulmonary edema whose mechanisms are not completely understood but it is believed that increased inspiratory pressure can generate a very low subatmosferic pressure in the pleural space, resulting in a pressure gradient favouring fluid from the pulmonary capillaries into the pulmonary interstitium and alveoli (Reiter & Holt, 2012).

9.1 EMERGENCY TRACHEOSTOMY

Tracheostomy is performed in upper airway obstructions situations, when it is necessary to bypass the airflow directly into the trachea to secure patient ventilation (Mercurio, 2011).

In one study (Davidson *et al*, 2001) dogs with BAS that underwent tracheostomy had a more significant rate of postoperative complications and improved more slowly in the postoperative period as a result of the tracheostomy procedure. Consequently, tracheostomy is only warranted in dogs that have complications during surgery and recovery.

Temporary tracheostomy must be performed in a controlled manner, with the patient under general anaesthesia with an endotracheal tube placed and a proper surgical scrub of the surgical site (Fudge, 2015). Permanent tracheostomy should be considered a last resource procedure (Fudge, 2015)

Multiple factors are involved in the decision to perform a postoperative temporary tracheostomy. Patient factors include the degree of preoperative airway swelling, BOAS severity, extent of the intraoperative trauma, the ease of recovery and predisposition (Trappler & Moore, 2011). Good postoperative assessment of the patient's ventilatory status, such as capnography, pulse oximetry and blood gas analysis aids in the decision making process and these parameters should also be monitored after the procedure (Trappler & Moore, 2011).

There are different types of tracheostomy tubes: cuffed, uncuffed, with or without an inner canula (Fudge, 2015). The choice of the tube depends on individual patient factors. The cuffed tube is used when positive pressure is required to ventilate the patient (Fudge, 2015). The uncuffed tube is used in most situations as it reduces the likelihood of tracheal damage and the use of a tube with an inner cannula allows for easy and effective maintenance of the tracheal tube as it allows cleaning and maintenance of airway patency (Fudge, 2015).

The size of the tracheostomy tube is based on the internal diameter of the patient trachea and a lateral cervical radiograph can be taken to help estimate the size with the largest tube than can be easily accommodated in the trachea being selected (Fudge, 2015). Hedlund (1991) reports that the tracheostomy tube must be larger than 50% of the diameter of the trachea. It is worthwhile taking into account that tubes that are too large and/or whose cuff is over inflated can lead to ischaemia and possible tracheal stenosis due to the increase pressure in the trachea wall (Mercurio, 2011).

The two most common approaches for temporary tracheostomy are transverse and vertical incisions (Fudge, 2015).

Placement of temporary tracheostomy tube using a transverse incision of the annular ligament is described as advantageous because no tissue is removed from the tracheal wall and the cartilage rings are not disrupted (Mercurio, 2011). The tracheal incision is made between the third and fourth tracheal rings and it must be less than 50% of the tracheal circumference (Fudge, 2015). One of the risks for this procedure is damaging the recurrent laryngeal nerve, with will lead to laryngeal paralysis (Fudge, 2015).

In the vertical incision approach, a midline incision through the two to four tracheal rings is made and the long term risk of this procedure is segmental lateral tracheal collapse (Fudge, 2015).

In both techniques, a space must be left between the tracheostomy tube and the skin and muscles, so that air can easy escape to prevent subcutaneous emphysema (Fudge, 2015).

A tracheostomy tube requires a high level of maintenance such as regular cleaning to prevent obstruction of the airways by secretions to reduce the risk of complications such as nosocomial infection and trauma (Fudge, 2015). Removal and cleaning of tubes with inner canula should be performed every four hours and tubes without inner canula must be replaced completely every 24 hours (Fudge, 2015.) These patients must be closely monitored until the temporary tracheostomy tube is removed as obstruction by mucus/blood or displacement of the tube leads to asphyxiation and death (Mercurio, 2011).

The most common reported complications are gagging, vomiting and couching, obstruction and displacement (Mercurio, 2011).

10.0 WELFARE CONSEQUENCES

Brachycephaly is a pure manmade disease, some breed standards may be encouraging breeders to select for dogs predisposed to disease (Oechtering, 2010; Asher, Diesel, Summers, McGreevy & Collins, 2009). Changes to the conformation and subsequent health of future dogs lies with the breeders, who are the stakeholders of breeding decisions (Packer, Hendricks & Burn, 2012). They are highly motivated to maintain the breed standards, selecting for exaggerated features, however they don’t seem to understand that these standards are detrimental to the health and quality of life of the dog (Packer, Hendricks & Burn, 2012; Oechtering, 2010). Following these criticisms of pedigree dogs, the UK Kennel Club has responded with several initiatives raising awareness to breeders, such as “Fit For Function: Fit For Life” a 2008 Kennel Club campaign (Packer, Hendricks & Burn, 2012). However this did not change the breeders perspective since the breed standards and ideal features were not updated by the Kennel Club (Packer, Hendricks & Burn, 2012).

Sixty three disorders were recently identified as directly related to conformation traits in the top 50 UK Kennel club breeds (Asher, Diesel, Summers, McGreevy & Collins, 2009). In these authors review, one of the disorders identified as most severe according to the Generic Illness Severity Index for Dogs was BOAS.

BAS has severely welfare consequences, with the most affected dogs described as having “little or no activity” as they are fully occupied just with breathing and any form of stress, excitement or exercise can cause severe respiratory distress leading to collapse and death (Packer, Hendricks, Tivers & Burn, 2015).

Brachycephalic breeds, such as English and French bulldogs, Pugs and Boxers have become especially popular in the last years (O'Neill *et al*, 2015; Oechtering, 2010). In addition, an increasingly high percentage of brachycephalic breeds suffers BOAS which consists in anatomical abnormalities that lead to respiratory compromise (O'Neill *et al*, 2015). Furthermore, due to a normalization phenomenon that recognised as "normal" breed-associated breathing problems, there may be under-reporting and under diagnosis of BAS given that recognition of the clinical signs by the owner is an important initial step to realize the problem and seek veterinary attention (O'Neill *et al*, 2015; Packer, Hendricks & Burn, 2012). The lack of perception of clinical signs and veterinary attention are important limitations that negatively affect the animal's welfare and despite the high frequency and severity of BOAS signs 58% of owners did not perceive that their dogs had breathing problems (Packer, Hendricks & Burn, 2012). In the same study brachycephalic dog owners were more tolerant of clinical signs of airway obstruction than non-brachycephalic owners and therefore they tolerated a greater degree of respiratory compromise in their pets before seeking help.

The chronic nature of clinical signs are accepted by owners and are perceived as normal. This is problematic since it means that many brachycephalic dogs are experience negative effects on their welfare without serious appreciation of their clinical signs by their owners (Packer, Hendricks & Burn, 2012).

11.0 SLEEP APNOEA

Hendricks, Kline, Kovalski, O'Brien, Morrison & Pack (1987) reported that sleep apnoea occurs when patients have normal breathing during waking hours but experience repetitive, usually obstructive, apnoeic episodes when sleeping (*in* Hoareau, Jourdan; Mellema & Verwaerde, 2012). This complete upper airway collapse during sleep that can result in intermittent nocturnal hypoxemia and systemic hypertension (Hoareau, Jourdan; Mellema & Verwaerde, 2012). Suffocation is mainly observed during sleep due to general muscular relaxation that narrows even more an already narrowed airway (Koch *et al*, 2003).

The English bulldog is a natural model for sleep apnoea studies in humans due to their altered upper airway anatomy and tendency to snore – they exhibit all the hallmarks of sleep apnoea in humans (Hendricks, 2004):

- Hypersomnolence: Despise being in the lab the bulldogs were able to fall asleep in 15 minutes, while in a normal dog would take a long period of habituation.

- Snoring

- Obstructive apnoea (detected by paradoxical movement between ribcage and abdomen) and central apnoea (cessation of respiration).

- Decreases in oxygenation

In bulldogs, upper airway muscles actively maintain the pharyngeal portion open during inspiration (Hendricks, 2004). The sternohyoideus muscles dilate the pharynx during awake breathing, however their activity decreases during sleep (Reiter & Holt, 2012). During the rapid eye movement (REM) sleep, the decrease sternohyoideus muscle activity may lead to an apnoeic episode, especially in bulldogs (Reiter & Holt, 2012). This pattern of upper airway muscles hyperactivity was also found in humans with sleep apnoea (Hendricks, 2004).

During the apnoeic episode, once hypoxemia is sensed and the peripheral chemoreceptors (vagus and accessory nerve conduct impulses to higher respiratory centre to increase ventilation) are triggered, the animal abruptly awakens and the muscles involved in the upper airway opening rapidly and strongly contract (Hoareau, Jourdan; Mellema & Verwaerde, 2012).

With time, this chronically and abrupt change in muscular tone leads to inflammation, oedema and fibrosis which diminishes the ability of the muscle to maintain upper airway patency and worsening the obstruction (Hoareau, Jourdan; Mellema & Verwaerde, 2012). Hendricks (2004) hypothesized that the chronic load and pattern of the muscles lead to myopathic changes (oedema and fibrosis) that interferes of the muscle capacity to maintain an open pharynx, culminating in a deterioration of sleep apnoea and a shorter life expectancy. These findings were also detected in humans (Hendricks, 2004).

Hendricks (2004) also studied the cardiovascular consequences of sleep apnoea and placed a permanent arterial femoral catheter in bulldogs to collect continuous information about arterial blood pressure. The arterial blood pressure increase during sleep and that it was even higher during snoring inspiratory effort, this suggests a neural rather than mechanical cause (Hendricks, 2004). The authors believe that this pressure changes can lead to cardiac abnormalities in older dogs – in the study two of the older dogs developed dilated chambers and decrease wall motion.

The treatment for human sleep apnoea is the use of a positive airway pressure mask. This is not applicable to dogs, being the only resource a BOAS procedure (Hendricks, 2004). Hendricks study sleep apnoea in two dogs that underwent a BOAS procedure, only one of them improve, the other one remained the same.

Hendricks (2004) believes that more investigation is needed in this area to achieve a long term treatment for bulldogs with sleep apnoea.

CHAPTER III – STUDY WITH SIX CLINICAL CASES

1.0 OBJECTIVE

This prospective study aims to characterize a small sample of six brachycephalic dogs, relating their breed, age, gender, clinical presentation, primary abnormalities and secondary changes detected. According to their clinical presentation the patients underwent individual surgical correction.

2.0 PROCEDURES

For this study six brachycephalic dogs were evaluated for BOAS and surgical treatment during the student placement. The information gathered for each patient consist of signalment, clinical signs, medical investigation, surgery and short term outcome.

All of the six patients were closely monitored by the student, but the investigation procedures for BOAS changes were decided and performed by the clinician and/or surgeon responsible for the case.

The primary method of investigation was clinical examination under anaesthesia. Some patients underwent a much more detailed investigation with CT, endoscopy or radiographs.

3.0 RESULTS

3.1 SAMPLE

The study sample consisted in six (n = 6) brachycephalic dogs referred for further BOAS investigation that were followed by the student during their hospitalization.

From this pool sample 50% of dogs were pugs (n = 3), 17% were French bulldogs (n = 1) and 33% were English bulldogs (n = 2). All the animals from this study were males, 100% (n = 6), being just 16.67% neutered (n = 1) (Table 1).

Their age varied between 5 months to 5 years old.

Table 1 summarizes the group sample of this study.

Signalment	Breed	Age	Gender	Neuter	Weight (kg)
Case 01	Pug	5 years	Male	Yes	9.100
Case 02	French bulldog	1 year	Male	No	15
Case 03	Pug	2 years	Male	No	8.500
Case 04	Pug	1 year	Male	No	9.700
Case 05	English bulldog	6 months	Male	No	15.000
Case 06	English bulldog	5 months	Male	No	13.000

Table 1. Signalment of the dogs from this BOAS study

3.2 PRESENTATION

For this study brachycephalic breeds were referred for further investigation and surgical correction of BOAS. During this study the student followed the cases through their hospitalization, including the first appointment with the client.

Two cases were followed at the Vets Now Referral hospital and the remaining four cases were followed at the Highcroft Veterinary referrals.

During the first presentation all dogs, 100%, presented stertous breathing and exercise intolerance (n = 6). The degree of stertous breathing varied between patients, but it was always present.

Regurgitation was reported by the owner in 50% (n = 3) of cases. It was very important to explain the difference between vomiting and regurgitation for the owner since many of them initially reported vomiting instead of regurgitation. Such as regurgitation, retching was reported in 50% (n = 3) of cases.

Asking the owners about coughing is of extremely importance, since it can indicate further complications such as aspiration pneumonia. Half, 50% (n = 3), of owners reported coughing during consultation. Only case 06 presented coughing without retching.

During the consultation only 66.66% (n = 4) of dogs were panting.

Collapse was reported in 33.34% (n = 2) of cases. Case 03 and 06 were referred as an emergency due the history of collapse.

Table 2 summarizes the cases presentation during the appointment with the owners.

Presentation	Stertous breathing	Exercise intolerance	Regurgitation	Retching	Coughing	Panting	Collapse
Case 01	✓	✓	✗	✓	✓	✗	✗
Case 02	✓	✓	✓	✗	✗	✓	✗
Case 03	✓	✓	✗	✓	✓	✗	✓
Case 04	✓	✓	✓	✓	✗	✓	✗
Case 05	✓	✓	✗	✗	✗	✓	✗
Case 06	✓	✓	✓	✗	✓	✓	✓

Table 2. Representation of the sample presentation. ✓:reported during consult. ✗: not reported during consult.

3.3 CLINICAL EXAMINATION

During the first appointment the only parameter from the BOAS that could be investigated was the stenotic nares. All patients, 100% (n = 6), had stenotic nares (Fig. 07). Being the more severe when compared with case 02.

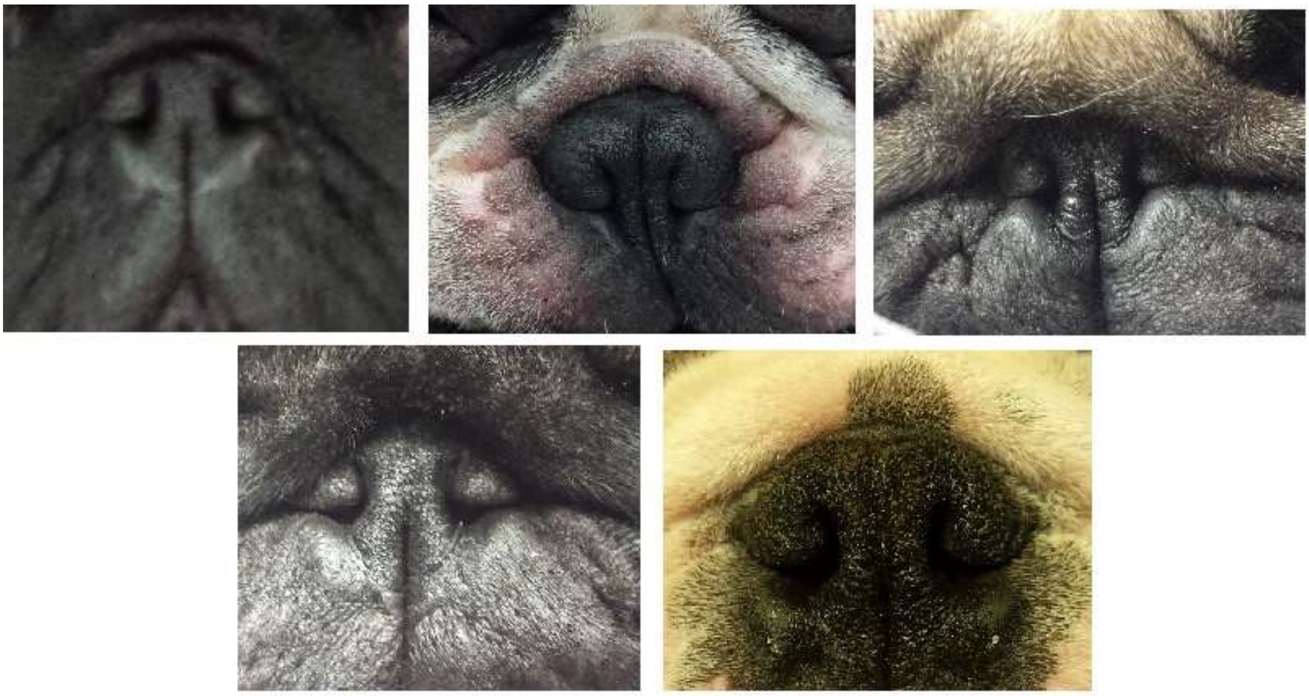


Fig. 07. Stenotic nares before rhinoplasty. Top left: Case 01. Top middle: Case 02. Top right: Case 03. Bottom left: Case 04. Bottom right: Case 05. (Original pictures).

The other BOAS components, such as elongated soft palate and laryngeal collapse required general anaesthetic for investigation.

The majority of cases (case 02, 03, 04 and 05) were pre-medicated with ACP and methadone. Case 01 was pre-medicated with buprenorphine and midazolam, due to his anxious character. Table 3 refers to the doses used in each patient. On case 06 all BOAS investigations were performed post-mortem.

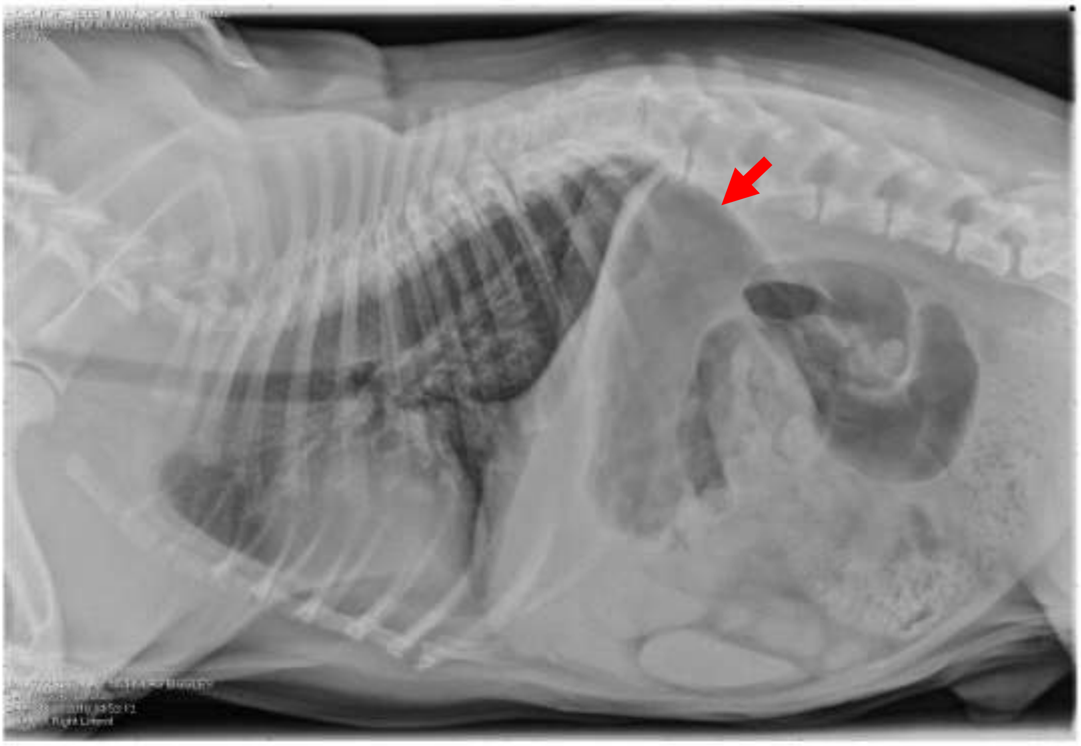
Cases 02 and 04 received higher doses of methadone. Case 02, besides BOAS procedures, also had bilateral mild external ear disease with thickening of the inner pinna. And case 04 besides the BOAS procedures also underwent castration and umbilical herniorraphy.

All patients had a period of pre-oxygenation prior and during sedation, by flow technique, before induction with propofol. The general anaesthetic was maintained with isoflurane plus oxygen.

	Buprenorphine (mg/kg)	Midazolam (mg/kg)	ACP (mg/kg)	Methadone (mg/kg)	Via	Pre - oxygenation	Propofol (mg/kg)
Case 01	0.02	0.2			IM	Flow by	4
Case 02	-	-	0.01	0.2	IM		
Case 03	-	-	0.005	0.1	IV		
Case 04	-	-	0.01	0.2	IV		
Case 05	-	-	0.01	0.1	IV		
Case 06	-	-	-	-	-	-	-

Table 3. Pre-medications given to each patient.

The BOAS investigations varied between both practices and owners financial capability. Case 01 and 02 had a full investigation including pre-anaesthetic blood tests (blood gases, creatinine, glucose, electrolytes and PCV/TS), direct observation of the larynx with a laryngoscope, CT scan, bronchoscopy and BAL. Case 03, 04 and 05 investigation included pre-anaesthetic blood tests (haematology with renal and hepatic parameters) and direct observation of the larynx with a laryngoscope under anaesthesia. Due to the high frequency of regurgitation reported by the owner, two radiographs thoracic views were taken on case 04 to rule out aspiration pneumonia – no abnormalities were found. On case 05 thoracic radiographs were also taken due to risk of hypoplastic trachea, since it was a bulldog – no abnormalities were found aside from an increased amount of aerophagia which is compatible with BOAS (Fig. 08). On case 06 the investigation was performed after euthanasia by direct observation of the soft palate and laryngeal saccules.



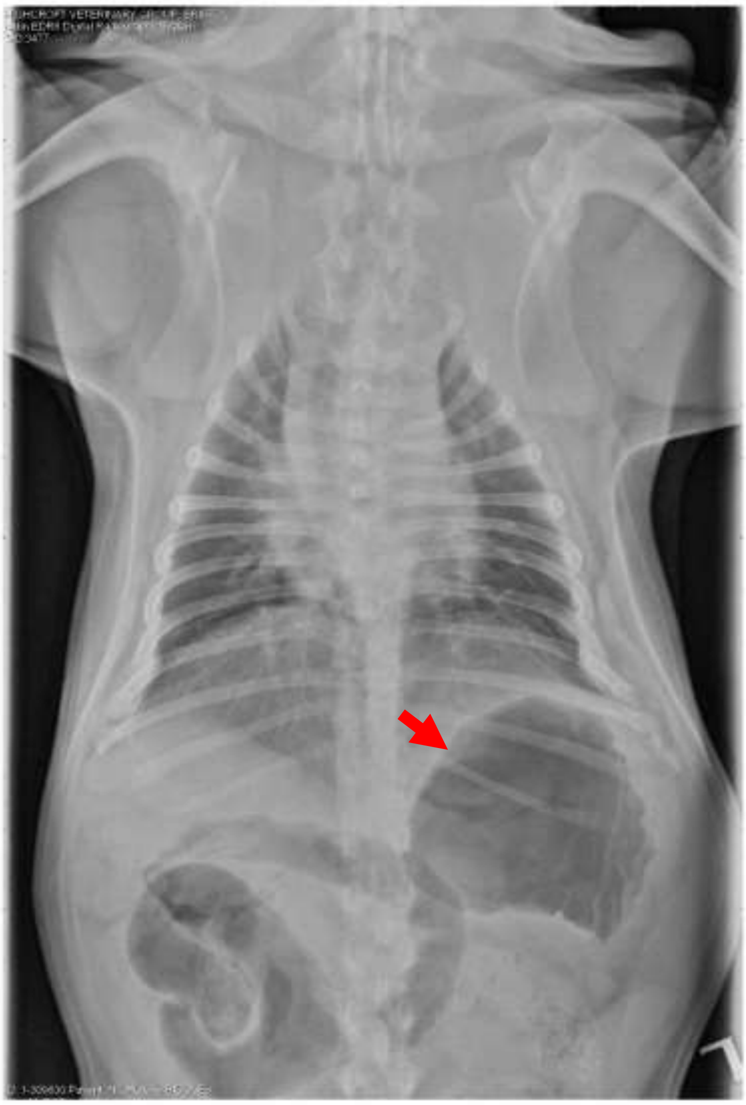


Fig. 08. Case 05. Top: Right lateral thorax. Bottom: Thorax VD - note the aerophagia indicated by the red arrows. (Original radiographs)

The CT scan of the thorax from Case 01 revealed a subjectively enlarged heart (without evidence of heart failure), which caused mild dorsal displacement of the trachea. There was also severe collapse of the left mainstream bronchi, which caused a dramatic reduction in air filling of that hemithorax, leading to a mediastinal shit to the left (Fig. 09). There was also evidence of protrusion of the liver parenchyma into the thoracic cavity, which caused a mild cranial advancement of the right caudo-dorsal lung lobes. This would be consistent with a diaphragmatic hernia which is likely an incidental finding, probably congenital in origin but unlikely to be clinically significant.

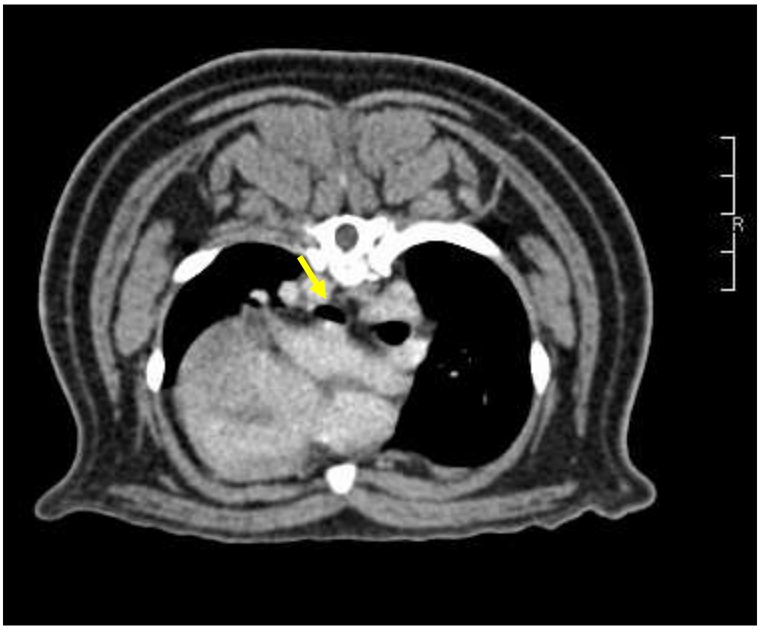


Fig. 09. Case 01. Left main bronchus (arrow) is compressed leading to reduction in air filling of the left hemithorax and a left mediastinal shift. (Original CT picture)

On this same patient a bronchoscopy revealed stage II laryngeal collapse (everted laryngeal saccules and apposition of corniculate cartilages) and oedema. The trachea at the carina level had a grade I static collapse with a dynamic component exacerbating the collapse to grade III. The rest of the trachea had a grade II to III static collapse from the entrance of the thorax to the region of the larynx and in addition had a dynamic component of collapse that was in some areas almost grade III (close to 75% reduction in lumen). The left main bronchus had a grade IV static collapse (Fig. 10) and the right caudal bronchus had grade II dynamic collapse.

It was only possible to perform a right side BAL due to severe collapse of the left side. Cytology revealed a mild neutrophilic inflammation and on culture there was scant growth of *Streptococcus* beta-haemolytic, which was sensitive to most antibiotics. Two weeks of antibiotic treatment with amoxicillin and clavulanic acid (20 mg/kg PO BID) was initiated.

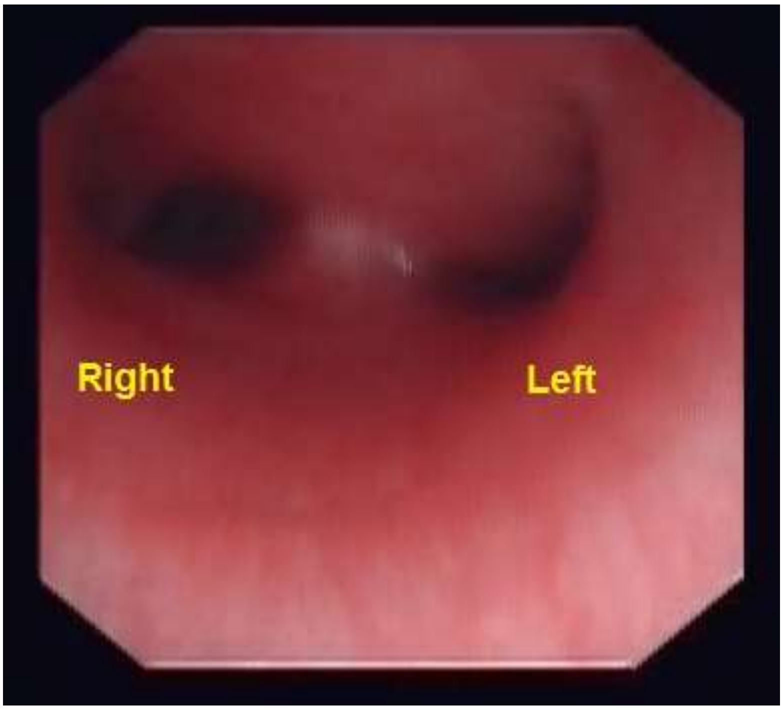


Fig. 10. Case 01: Severe collapse of the left main bronchus - grade IV of static collapse. (Original endoscopy picture)

Case 02 bronchoscopy revealed a moderate inflammation of the trachea and main bronchus. There was evidence of grade IV static collapse of the main branch of the right caudal lung lobe and also a grade II to III static collapse of branch in the left cranial bronchus. Bilateral BALs were performed. Cytology was unremarkable and culture was negative. PCR was positive for *Bordetella bronchiseptica* and *Mycoplasma canis*. These organisms can be found as intrinsic flora in normal dogs. However, given the increased risk of respiratory issues, it was initiated an antibiotic protocol as a preventive measure. Being so, despite the lack of clinical signs of pneumonia the clinician elected to treat the patient with doxycycline.

Case 03 anatomical abnormalities revealed itself to be worse than expected. This patient was referred due to a collapse at the previous vet, however during the consult the patient seemed very comfortable and with a mild stertous breathing. With the direct observation of the larynx with a laryngoscope, asides from the elongated soft palate (Fig. 13), secondary changes were found – laryngeal collapse stage III and everted laryngeal saccules with an overall very narrow pharynx.

Case 04 had an excessive amount of folded skin above the nose, which was thought to worsen the airflow through the nares. During direct observation of the larynx with a laryngoscope the soft palate did not seem elongated, which was slight unexpected. No laryngeal collapse was noted. Despite the stenotic nares, this patient did not show any other signs of BOAS. The soft palate was not elongated, which was a surprise given the prominent history of GI signs which created some concern about the possibility of sliding hiatal hernia. Due to financial reasons the possible sliding hiatal hernia wasn't investigated.

Case 05 was a very young patient (6 months). For precaution thoracic radiographs were taken to rule out aspiration pneumonia and possible hypoplastic trachea since the patient was an English bulldog (Fig. 08). Assessment of the nasopharynx revealed a mildly elongated soft palate, no laryngeal collapse and bilateral tonsils enlargement (Fig. 11).

Fig. 11. Note the enlargement of the right tonsil (arrow). (Original picture).

Case 06 was admitted as an emergency case due history of collapse. This patient has had a very noisy breathing since being in owner's possession, and soon after developed cough, vomiting and pyrexia. He received antibiotic treatment at the previous vet to which he was unresponsive. The previous vet decided to do further investigation – BAL and thoracic radiographs – and reported an increased difficulty during intubation. The patient was then referred for a second opinion on the case.

Overall 100% of cases (n = 6) had stenotic nares and 83.34% (n = 5) had an elongated and/or thick soft palate. The only patient that did not show an elongated soft palate was case 04 which was a surprise since this patient owner reported some GI signs during his consult, making us suspect of a possible sliding hiatal hernia.

Excessive tissue on the nasopharynx was also a very frequent issue, 66.67% (n = 4), however it was not detected on case 04 and case 05.

Investigation to detect abnormal nasopharyngeal turbinates was limited and can only be performed by CT scan or by retroflexion of an endoscope dorsally and cranially behind the soft palate. A CT scan was only performed on case 01 and 02, in which no abnormal nasopharyngeal turbinates were detected. On the remaining cases no investigation was performed. This lead us to 0% (n = 0) of abnormal nasopharyngeal turbinates detected on this study.

Tracheal collapse and/or bronchial collapse was just investigated on cases 01 and 02 by bronchoscopy. On case 01 a grade II to III static collapse from the entrance of the thorax to the region of the larynx was detected. It was also detected a dynamic component of collapse that in some area of the trachea reached grade III (close to 75% reduction in lumen). The left main bronchus had a grade IV static collapse (Fig. 10) and the right caudal bronchus had a grade II dynamic collapse.

Case 02 bronchoscopy revealed a moderate inflammation of the trachea and main bronchi. There was evidence of grade IV static collapse of the main branch of the right caudal lung lobe and also a grade II to III static collapse of a branch in left cranial bronchus.

The remaining cases no bronchoscopy was performed.

All primary changes found are summarise on Table 4.

Primary changes	Stenotic nares	Elongated / thick soft palate	Excessive tissue on the nasopharynx	Abnormal nasopharyngeal turbinates	Hypoplastic trachea	Tracheal collapse	Bronchial collapse
Case 01	Present	Present	Present	Not detected	Absent	Grade III static. Grade II dynamic	Grade IV
Case 02	Present	Present	Present	Not detected	Absent	Not detected – just inflammation	Grade IV static
Case 03	Present	Present	Present	N. I.	N. I	N. I.	N. I.
Case 04	Present	Absent	Absent	N. I.	Absent	N. I.	N. I.
Case 05	Present	Present	Absent	N. I.	Absent	N. I.	N. I.
Case 06	Present	Present	Present	N. I.	Present	N. I.	N.I.

Table 4. Summary of the primary changes found on clinical examination. N.I = No investigation.

Relatively to secondary changes, laryngeal saccules eversion (stage I of laryngeal collapse) and other stages of laryngeal collapse were the most frequent secondary change found reaching 40% (n = 2) of investigated cases (n = 5).

Hiatal hernia and aspiration pneumonia were appropriately investigated, with respectively gastroscopy/CT and BALs, on case 01 and 02. No hiatal hernia was detected. Since case 01

BALs revealed a mild neutrophilic inflammation and *Streptococcus* beta-haemolytic growth but no signs of pneumonia were detected on CT, there could had been a start of pneumonia.

On case 02, similarly to case 01, no signs of pneumonia were detected on CT but BAL was positive for *Bordetella bronchiseptica* and *Mycoplasma canis.* This could have been a start of pneumonia.

On the remaining cases no BAL or bronchoscopy was performed.

Table 05 summarizes the secondary changes found in this study.

Secondary changes	Laryngeal saccules eversion	Laryngeal collapse	Hiatal hernia	Aspiration pneumonia
Case 01	Present	Stage II	Absent	Maybe
Case 02	Absent	Absent	Absent	Maybe
Case 03	Present	Stage III	N. I.	N. I.
Case 04	Absent	Absent	N. I.	N. I.
Case 05	Absent	Absent	N. I.	N. I.
Case 06	Absent	N. I.	N. I.	N. I.

Table 5. Summary of secondary changes found. N.I. = No investigation

3.4 SURGICAL TREATMENT

After the BOAS investigation the patients followed immediately to surgery which was performed under the same general anaesthetic. The only exception was case 01 in which the surgical procedures was performed a few weeks later due to logistical reasons which was not an ideal situation.

In this study the procedures performed were: rhinoplasty, palatoplasty and sacculectomy. No arytenoid lateralisation was performed. The procedures followed always this order – first sacculectomy (if necessary), followed by palatoplasty and rhinoplasty.

For the sacculectomy and palatoplasty, the patient is positioned in sternal recumbency, with the mouth fully open using strips of tape anchored to a metal frame (Fig. 12). Before starting the palatoplasty some dry swabs were placed in the pharynx to prevent blood from going into the trachea and oesophagus.

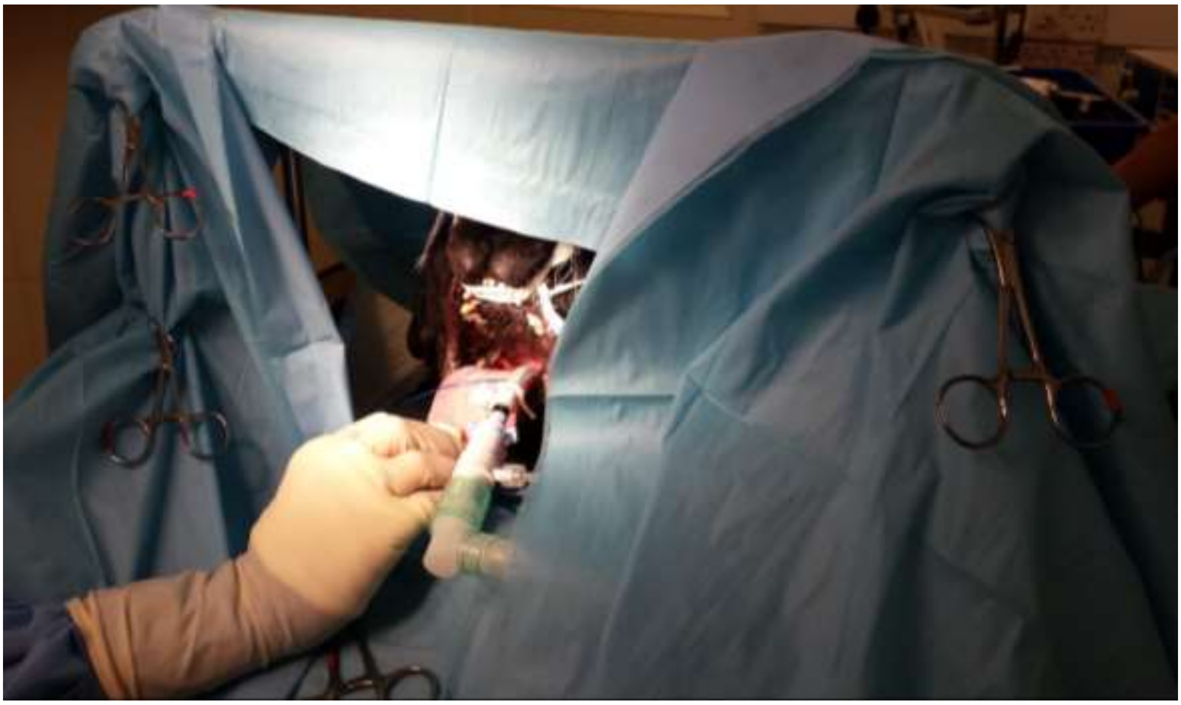


Fig. 12. Staphylectomy requires a sternal recumbency with the mouth fully open. Case 01. (Original picture).

For the rhinoplasty the patient is re-positioned in a sternal recumbency, with the head resting symmetrically on a pad. In all clinical cases the rhinoplasty technique of choice was the vertical wedge technique performed with a scalpel blade.

Some surgeons believe that inserting cotton buds inside the patient nose before performing the rhinoplasty prevents the formation of blood clots inside the patient's nose, which will improve comfort and good airflow after the procedure.

Always before recovering the animal from the anaesthesia, the soft palate was reassessed for any bleeding. And the nasopharyngeal swabs were removed.

Case number 01 had a stage II laryngeal collapse, which includes everted laryngeal saccules (stage I). Despite the laryngeal saccules eversion the surgeon opted not to remove them as they did not affect significantly the diameter of the rima glottis. The surgical procedure started with palatoplasty followed by rhinoplasty.

Case number 02 underwent palatoplasty and rhinoplasty. This patient had a larger amount of redundant pharynx soft tissue, which was also more thickened when compared with the pug from case 01.

Case 03 underwent a sacculectomy, palatoplasty (Fig. 13) and rhinoplasty. Once the laryngeal saccules were visualized they were grasped with a long haemostats forceps, retracted rostrally, and excised with a Potts Smith scissor. Haemorrhage was minimal.

Fig. 13. Left: Clamp is marking the excess of soft palate to be removed. Right: After the resection of the excess soft palate. (Original picture)

Case 04 surgical treatment only included rhinoplasty, since, as describe in the previous section, no laryngeal collapse was noted and the soft palate did not seem elongated.

Case 05 is a very young English bulldog, with only 6 months old. Due to this patient young age only rhinoplasty was performed despite the mildly elongated soft palate.

After analysing case 06 thoracic radiographs a severe hypoplastic trachea was diagnosed.

Fig. 14. Note the narrow trachea. The narrowing is present throughout the trachea extension. (Thanks to Helen Wilson for the picture and Golden Valley Veterinary Hospital for the radiographs)

Table 6 summarises all the surgical procedures made in this study.

Procedures	Rhinoplasty	Palatoplasty	Sacculectomy	Arytenoid lateralisation
Case 01	✓	✓	✗	✗
Case 02	✓	✓	✗	✗
Case 03	✓	✓	✓	✗
Case 04	✓	✗	✗	✗
Case 05	✓	✗	✗	✗
Case 06	--------------------------------------- *Euthanasia* ---			

Table 6. Surgical procedures. ✓: performed. ✗: not performed.

Rhinoplasty was the most common procedure. All patients accepted for surgery (n = 5) underwent a rhinoplasty (100%). Figure 15 represents the results after the rhinoplasty, those can be compared with figure 07 which represents the nares before the procedure.

The second most common procedure was palatoplasty. Of five (n = 5) patients accepted for surgery, three (n = 3) of them underwent a palatoplasty, representing 60% of the sample pool accepted for surgery. Sacculectomy was only performed in one (n = 1) patient of those that underwent surgical treatment (n = 5), representing 20% of cases in this study.

Although some patients were diagnose with laryngeal collapse, no arytenoid lateralization was performed.

Fig. 15. Stenotic nares after rhinoplasty. Top left: Case 01. Top middle: Case 02. Top right: Case 03. Bottom left: Case 04. Bottom right: Case 05. (Original pictures).

3.5 RECOVERY FROM ANAESTHESIA AND POSTOPERATIVE PERIOD

The anaesthesia recovery was made in a calm environment, and extubation was delayed in all patients in this study, until the animal was fully awake.

Most patient in this study had a remarkable anaesthetic recovery, being the only exception case 02. This French bulldog was a very anxious and agitated patient. Due his personality trades his recovery was troubled. Shortly after recovery from anaesthesia the patient was unsettled and with a deep stertours breathing. The postoperative care included sedation with a low dose of butorphanol (0.2 mg/kg IV), oxygen therapy and SpO_2 monitoring. Due to his history of vomiting, and a high risk of aspiration, it was also given omeprazole (1 mg/kg IV) and maropitant (0.1 mg/kg SC) during his hospitalization. Being this an unsettle patient, a post-operatively analgesia was continued with buprenorphine during the night (0.1 mg/kg IV qh4-qh5).

The remaining cases in this study had a calm and easy recovery, without any complications. In that same evening of the surgery the patients had a normal appetite, eating wet food in meatball shape.

On the next day after the surgical procedure the patients were discharged and sent home with the medication described on table 7.

	Omeprazole	Meloxicam	Amoxicillin with clavulanic acid	Procedures
Case 01	-	0.1 mg/kg PO SID	20 mg/kg PO BID for 7 days	Rhinoplasty and palatoplasty
Case 02	1 mg/kg PO SID for 2 weeks	0.1 mg/kg PO SID	20 mg/kg PO BID for 7 days	Rhinoplasty and palatoplasty
Case 03	1 mg/kg PO SID for 3 weeks	0.01 mg/kg PO SID for 5 days	-	Rhinoplasty, palatoplasty and sacculectomy
Case 04	1 mg/kg PO SID for 3 weeks	0.01 mg/kg PO SID for 5 days	-	Rhinoplasty
Case 05	-	0.01 mg/kg PO SID for 2 days	-	Rhinoplasty
Case 06	-	-	-	Euthanasia

Table 7. Represents the postoperative medication prescribed to each study patients.

In this study 83.34% (n = 5) of patients presented some form of GI sign – 50% (n = 3) regurgitation and 50% (n = 3) retching, but only 75% (n = 3) of patients that underwent surgical treatment (n = 4) received medical GI treatment.

3.6 PROGNOSIS

No patient in this study presented complications during surgery or postoperatively. Being so the prognosis was excellent in all patients that underwent surgical treatment in this study (n = 5) 100%. As expected some patients presented stertous breathing during the postoperative period.

A week after the surgical treatment a follow up phone call was made. All owners reported a more quiet breathing and an increase in energy, with longer walks and more play time.

The only case with a poor prognosis was case 06. This five months old English bulldog presented with a severe hypoplastic trachea with only 4 mm of diameter, which makes a ratio of 0.06. This severe hypoplastic trachea and associated with collapse episodes in such a young age. This case was euthanized since there was severe impact on his quality of life.

4.0 DISCUSSION

This BOAS study, despite of being a small study with only six clinical cases, its results were very similar to majors studies.

The major difference between this study and other author's studies is the age range. Meola (2013), Lodato & Hedlund (2012) and Moores & Anderson (2010) reports that the great majority of brachycephalic dogs are usually diagnosed at 2 or 3 years of age, however it can occur early, especially in English bulldogs and Pugs. This age range corresponds to 16.67% (n = 1) from the sample. However in Pugs and English bulldogs BOAS can be detected earlier, before 2 years of age, this new age range corresponds to 66.66% (n = 4) of patients in this small sample group, being 50% (n = 2) English bulldogs and 25% (n = 1) Pugs. Since this study's sample is mostly composed by Pugs and English bulldogs, this may explain the younger mean age at the time of diagnose – 1.68 years old.

During the consultation only 66.66% (n = 4) of dogs were panting. Brachycephalic dogs suffering from BOAS have a tendency to overheating leading to panting (Clarke, 2015). Panting is a major method of thermoregulation in dogs as it increases minute ventilation and enhances heat dissipation (Clarke, 2015). This increases airflow turbulence leading to inflammation and swelling of the airways causing further blockage of already narrowed airways (Lodato & Hedlund, 2012). Since this study was performed during winter is more likely that the panthing was related with stress instead of overheating.

Collapse was reported in 33.34% (n = 2) of cases. Case 03 and 06 were referred as an emergency due the history of collapse. Collapse is the most severe BOAS presentation aside with cyanosis (Lodato & Hedlund, 2012; Dupre, 2008; Clarke, 2015).

Several studies, such as Poncet, Dupre, Freiche & Bouvy, 2006; Dupre, 2008 and Riecks, Birchard & Stephens, 2007, report the most common abnormalities to be elongated soft palate, stenotic nares, laryngeal saccules eversion and laryngeal collapse.

This study also found similar results, being the most common abnormalities found to be stenotic nares, 100% (n = 6), followed by elongated soft palate, 83.34% (n = 5). Unfortunately the others BOAS components, such as abnormal nasopharyngeal turbinates and tracheal collapse weren't investigated in all dogs which may lead to non-real statistic results. Laryngeal collapse and laryngeal saccules eversion were both investigated in five of six dogs of this study, between these patients 40% of the sample pool were positive to these abnormalities.

Another issues similar to this one occurred with the investigation of the abnormal nasopharyngeal turbinates. In this study only two of six dogs were investigated for aberrant nasopharyngeal turbinates by CT scan, which were not detected, making this study with 0% (n = 0) of diagnosed aberrant turbinates. This small pool sample associated with the lack of investigation may have led to false results. According to Ginn *et al* (2008) aberrant nasopharyngeal turbinates are present in around 21% of brachycephalic animals. In this author study, 82% of dogs with aberrant nasopharyngeal turbinates were Pugs.

Another issue with the small pool sample is that all patients were male. The gender predisposition for BOAS is still under debate. O'Neill *et al* (2015) did not found evidence of sex predisposition for brachycephalic obstructive airway syndrome (BOAS), but some authors may report sex predisposition.

As described in the BOAS review, the primary changes of BOAS are stenotic nares, elongated soft palate, and in some cases aberrant nasopharyngeal turbinates and hypoplastic trachea (Meola, 2013; O'Neill *et al*, 2015; Lodato & Hedlund, 2012; Clarke, 2015). Some authors, like Koch *et al* (2003) include in BOAS enlarged tonsils, which was found on case 05 (Fig. 11).

The investigation procedures performed in each patient varied according to the owners financial capabilities. For this reason not all dogs underwent the same BOAS investigation protocol, which would allow a much more accurate data analysis. A simple investigation was composed just by direct observation of the larynx, with evaluation of the soft palate and larynx. If the patient was at risk of aspiration pneumonia or hypoplastic trachea, a two views thoracic radiographs would be taken. A more detailed investigation included direct observation of the soft palate and larynx, CT scan and bronchoscopy with BAL.

After the BOAS investigation the patients must immediately follow to surgery which is performed under the same general anaesthetic. The surgical procedure usually follows this order: sacculectomy, palatoplasty and rhinoplasty.

For the sacculectomy and palatoplasty the dog is positioned in sternal recumbency with the upper jaw suspended by a gaze or tape placed around the maxillary canine teeth. In this study only one patient (n = 1), the equivalent 20% of patients, that underwent to surgery (n = 5), underwent sacullectomy. For the resection of the laryngeal saccules the endotracheal tube needs to be pushed to one side, or visualization can be achieved with temporary extubation or temporary tracheostomy (Trappler & Moore, 2011). After achieving proper visualization resection was performed by sharp resection with a Potts smith scissor.

As it was mentioned on the BOAS review, the laryngeal saccules do not return to their normal position after combined palatoplasty and rhinoplasty (Cantatore *et al*, 2012). Knowing that and considering all the airway changes this patient presents any increase in the airway diameter will be beneficial. Therefore I believe the everted laryngeal saccules from case 01 should have been removed to help increase further the diameter of the upper airways, because in this brachycephalic patients any increased in the airway diameter it is helpful.

Before proceeding with palatoplasty swabs or gauze should be placed around the endotracheal tube at the level of the glottis to prevent blood leakage to the airways (Hedlund, 2007).

The surgeon must carefully assess the amount of soft palate to be removed before any other procedures, such as removal of everted laryngeal saccules (Lodato & Hedlund, 2012). Removal of too little soft palate will lead to suboptimal results and removal of too much soft palate will lead to nasopharyngeal reflux of food during eating, predisposing the dog to serious complications, such as aspiration pneumonia (Brown & Gregory, 2005).

Trappler & Moore (2011) suggest that the removal of too little tissue is preferred over removal of too much tissue because patients can undergo further surgery to correct a persistently long palate. The tip of the epiglottis and middle to caudal third of the tonsillar crypt are used as the landmarks for incision placement in the soft palate (Lodato & Hedlund, 2012). Reiter & Holt (2012) describe the caudal border of the palatine tonsils as their soft palate resection landmark, which must be assessed with minimal retraction of the tongue and palate.

For the rhinoplasty the patient needed to be re-positioned, the head is free from the metal frame, the mouth is close, and the mandible is resting on a pad with the head as straight and stable as possible (Schmiedt & Creedy, 2012). The technique performed in all patients of this study was vertical wedge. The haemorrhage was be controlled by pressure (Schmiedt & Creedy, 2012) or by suturing as quickly as possible which will reduce the bleeding significantly, allowing better visualization for the remaining suturing. It is important to remember that regardless the technique chosen both incisions must meet at the alar cartilage, creating the depth of the wedge (Trappler & Moore, 2011).

Case number 02 underwent palatoplasty and rhinoplasty. This patient had a larger amount of redundant pharynx soft tissue, which was also more thickened when compared with the pug from case 01. Dupre (2008) describes the folded flap palatoplasty technique to address pharyngeal and laryngeal obstruction. This technique achieves a reduction of the soft palate thickness and length, thereby relieving the nasopharynx and oropharynx obstruction. I believe this patient would have been a good candidate for a folded flap palatoplasty due the thickness of his soft palate.

Case 03 underwent rhinoplasty and palatoplasty, despite this patient having a stage III laryngeal collapse, no surgical procedures were done on the larynx. It is sensible to not undertake any further surgical correction at this stage since despite having advanced laryngeal collapse there is no associated clinical signs. The correction of primary BOAS components may prevent further progress of laryngeal collapse.

Case 05 refers to a six months old English bulldog, which only underwent rhinoplasty despite having a mildly elongated soft palate. There is a possibility that the soft palate will adjust itself as the animal grow. Palatoplasty could have been performed but there is a risk of the soft palate becoming too short as the animal become fully grown, which could lead to further complications.

Case 06 was euthanized due severe hypoplastic trachea. This patient was a five months old English bulldog. To diagnose tracheal hypoplasia, the tracheal diameter is measured at the thoracic inlet and expressed as a ratio of the thoracic inlet height (Reiter & Holt, 2012). A hypoplastic trachea is defined as a ration of less than 0.13 for bulldogs (Miller & Gannon, 2015) (Fig. 14). This patient had a ratio of 0.06, with a diameter of 4 mm, which made oxygenation a difficult process for him, almost like breathing through a straw. His clinical presentation included coughing without retching, it is now clear that the hypoplastic trachea was the cause of coughing.

Despite the option of surgical treatment of the other BOAS components, such as stenotic nares and elongated soft palate, it would have little or no impact at all on the quality of life of this patient. The surgical and medical team specialists were all in agreement that surgery would not be on this patient interest, as there is nothing that can be done to increase his tracheal diameter. After euthanasia, an oral examination revealed a not over-long soft palate and normal laryngeal saccules, meaning that all his respiratory distress was due his hypoplastic trachea.

Recovery from anaesthesia is always a delicate moment since brachycephalic patient’s have a higher risk of airway obstruction on extubation due to the disease itself (Mellema & Hoareau, 2015). The recovery from anaesthesia must be slow and quiet, and endotracheal tube must be left in place for as long as the dog tolerates it (Moores & Anderson, 2010).

Recovery and postoperative period requires always monitoring of the patient for 24 to 48 hours (Trappler & Moore, 2011). In troubled recoveries sedating the patient is always sensible to prevent post-surgical trauma and unnecessary stress, while closely monitoring the patient and making sure that equipment is readily available to secure the airways if an emergency occurs (Lodato & Hedlung, 2012).

During the postoperative period food and water should be withdrawal for 12 to 24 hours and after that period a small amount of food can be offered under supervision (Reiter & Holt, 2012). Hedlund (2007) reports that hand-feeding of soft meatballs of humid food helps to slow ingestion and prevent dysphagia. The diet should consist of only soft food for 10 to 14 days, to minimize irritation of the upper airway (Trappler & Moore, 2011).

In this study 83.34% (n = 5) of patients presented some form of GI sign – 50% (n = 3) regurgitation and 50% (n = 3) retching. Mercurio (2001) refers that patients with GI signs should receive adequate medical treatment before or in combination with the BOAS surgery, such as an omeprazole course, to improve prognosis and decrease the risk of complications. As we can see from table 7, only 75% (n = 3) of patients that underwent surgical treatment (n = 4) received medical GI treatment. Regarding the use of antibiotics, it is majorly the surgeon's choice.

No patient in this study presented severe complications during surgery or postoperatively. The prognosis depends on a number of factors, such as patient temperament on the postoperative period, severity of airway pathology, surgical technique, and whether a temporary tracheostomy is required in the postoperative period (Trappler & Moore, 2011).

The general prognosis is excellent, but unfortunately with most surgical techniques the soft palate resection procedure does not have an effect on the redundant pharyngeal folds and thickness (Moores & Anderson, 2010). This means that the pharynx may continue to look very narrow despite palatoplasty and the stertous breathing may continue after the surgical treatment (Moores & Anderson, 2010).

As expected some patients presented stertous breathing during the postoperative period. This is a consequence of prolonged transoral endotracheal intubation, required for anaesthesia, that promotes oral, pharyngeal and laryngeal oedema, and oropharyngeal inspiratory muscle weakness, which further increases the airflow resistance leading to stertous breathing after the palatoplasty (Mellema & Hoareau, 2015). Due this relaxation and oedema of the pharynx the patient anaesthetic recovery must be slow and quiet, and endotracheal tube must be left in place for as long as the dog tolerates it (Moores & Anderson, 2010).

5.0 CONCLUSION

Brachycephaly is a pure manmade disease (Oechtering, 2010; Asher, Diesel, Summers, McGreevy & Collins, 2009). Animals like this wouldn't be created by nature itselft. Changes to the conformation and subsequent health of future dogs lies with the breeders, who are the stakeholders of breeding decisions (Packer, Hendricks & Burn, 2012).

Despite the fact of this study was based in a very small pool sample not allowing it to have statistic relevance, it showed that its BAS is a real life issue affecting our daily patients. It is imperative to bring awareness to owners explaining that "breed related noises" aren't normal, and need to be solved care off before other the damage is too severe. The lack of perception of clinical signs and veterinary attention are important limitations that negatively affect the animal's welfare and despite the high frequency and severity of BOAS signs 58% of owners did not perceive that their dogs had breathing problems (Packer, Hendricks & Burn, 2012). This make BOAS a welfare issue.

All patients from this study presented stertous breathing and exercise intolerance, being these two clinical signs reported by the owner. The younger the BOAS patient undergo surgery better it is to prevent secondary changes and improve quality of life. Trappler & Moore (2011) are the opinion that general practitioners, who are comfortable with the procedures, should offer correction of the nares and an elongate soft palate the time of castration.

The prognosis is good despite the surgical risks. It is important to remember that a medical management associated with weight clinic is imperative is this syndrome.

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